State of the Estuary 2000

Restoration Primer

San Francisco Bay
Sacramento-San Joaquin River Delta
Estuary

San Francisco Estuary Project

A Note on Citations

This report includes a mixture of original unpublished and published research presented at the March 1999 State of the Estuary (SOE) conference (noted as "Author, SOE, 1999" for oral presentations and "Author, SOE Poster, 1999" for posters) with fuller references listed on pp. 73 & 76);and summaries of other research (noted as "Author, Year" with a bibliography on p.76). Some of the secondary, supporting bibliographic references may be absent from page 76 due to a data loss that occurred at press time. To get these references, please email the authors or contacts listed in the section of your interest.

A Note to State of the Estuary Conference Participants

Thank you to all those who responded to our call for updated abstracts after the conference. The San Francisco Estuary Project appreciates your extra work in helping us put together this report (and your patience with its delayed production). Due to budget and space constraints, information from some posters and presentations could not be included in this report, especially if not submitted in digital form as requested soon after the conference. Apologies to any of those who we were not able to include. Information from all posters and presentations can still be found in the original conference abstract book. For a full bibliography of all conference presentations and posters, see page pp.73-75. Updated abstracts on the following (not included in this report) may be obtained by emailing bayariel@earthlink.net: Stress Proteins in Asian clams (Werner); Climate Influence on Diatoms (Starrat); Mercury Discharge Sources (Moran); Water Hyacinths and the Food Web (Toft); Processes Affecting Benthic Flux in Trace Metals (Kuwabara); Legacy of Watershed Management (Mumley); and Land Use & Restoration (Binger). Thank you all again from the San Francisco Estuary Project.

Published by the San Francisco Estuary Project, August 2000.

To order additional copies, send $5 per copy for shipping and handling (payable to Friends of the Estuary) to:

S.F. Estuary Project
Attn: State of the Estuary 2000
1515 Clay Street, #1400
Oakland, CA 94612
(510)622-2321
hb@rb2.swrcb.ca.gov

REPORT CREDITS

SFEP Program Manager

Marcia Brockbank

Conference Director

Joan Patton

Report Editor

Ariel Rubissow Okamoto

Contributing Editors

Cariad Hayes & Lisa Owens Viani

Proofreading

Rebecca Taggart

Photography

All photos ©copyright Bob Walker/IDG Films, except those on Perspective pages and those on pp. 8, 11, 33, 34, 35, 42, 48, 50, 58, 62, 70, 71 and 72 (fish)

Design

Darren Campeau
www.dcampeau.com

Printing

Alonzo Printing, Hayward, California

Special thanks to the S.F. Estuary Institute and the U.S. Fish & Wildlife Service for help with maps and graphics.

WHO, WHAT & WHY

This Report describes the current state of the San Francisco Bay-Sacramento-San Joaquin Delta Estuary's environment — waters, wetlands, wildlife, watersheds and the aquatic ecosystem— and provides restoration recommendations.

San Francisco Bay and the Delta combine to form the West Coast's largest estuary, where fresh water from the Sacramento and San Joaquin rivers and watersheds flows out through the Bay and into the Pacific Ocean. In the early 1800s, the Bay covered almost 700 square miles and the Delta's rivers swirled through a vast Byzantine network of 80 atoll-like islands and hundreds of miles of braided channels and marshes. Back then, almost a million fish passed through the Estuary each year and 69 million acre-feet of water crashed down from mountain headwaters toward the sea. But in 1848 the Gold Rush began and hydraulic mining plugged the rivers and bays with more than one billion cubic yards of sediments. Over time, farmers and city builders filled up more than 750 square miles of tidal marsh and engineers built dams to block and store the rush of water from the mountains to the Estuary, and added massive pumps and canals to convey this water to thirsty cities and farms throughout the state.

Today's Estuary encompasses roughly 1,600 square miles, drains more than 40% of the state (60,000 square miles and 47% of the state's total runoff), provides drinking water to 22 million Californians (two-thirds of the state's population) and irrigates 4.5 million acres of farmland. The Estuary also enables the nation's fourth largest metropolitan region to pursue diverse activities, including shipping, fishing, recreation and commerce. Finally, the Estuary hosts a rich diversity of flora and fauna. Two-thirds of the state's salmon and nearly half the birds migrating along the Pacific Flyway pass through the Bay and Delta. Many government, business, environmental and community interests now agree that beneficial use of the Estuary's resources cannot be sustained without large-scale environmental restoration.

This *State of the Estuary 2000* Report summarizes restoration and rehabilitation recommendations drawn from the 29 presentations and 99 posters of the 1999 State of the Estuary Conference and from related research. It also provides some vital statistics about changes in the Estuary's fish and wildlife populations, pollution levels and flows over the past three years, since the 1997 *State of the Estuary* report was published.

The report and conference are all part of the San Francisco Estuary Project's ongoing efforts to implement its *Comprehensive Conservation and Management Plan* (CCMP) for the Bay and Delta and to educate and involve the public in protecting and restoring the Estuary. The S.F. Estuary Project's CCMP is a consensus plan developed cooperatively by over 100 government, private and community interests over a five-year period and completed in 1993. The project is one of 28 such projects working to protect the water quality, natural resources and economic vitality of estuaries across the nation under the U.S. Environmental Protection Agency's National Estuary Program, which was established in 1987 through Section 320 of the amended Clean Water Act. Since its creation in 1987, the Project has held four State of the Estuary conferences and provided numerous publications and forums on topics concerning the Bay-Delta environment.

CONTENTS

To find the page number of a specific paper or author, see the conference bibliography. See also note to conference presenters, opposite.

EXECUTIVE SUMMARY

Conference Overview Article reprinted from *ESTUARY* newsletter, April 1999

WISING UP ON REHAB

"An ecosystem shaken to its roots," is the way editor Bill Jordan of the University of Wisconsin described the Bay-Delta watershed at the March 1999 State of the Estuary Conference. By the time the conference wound to a close, one thing had become very clear: though the idea of "restoration" has the power to make us all fired up and "dewey-eyed," as Jordan put it, the practice is a far less straightforward endeavor. The government may be spending billions on restoration to soothe the smoldering California water wars, but there's no guarantee that unhitching a few of the shackles binding the estuarine workhorse is going to make it break into a joyful gallop.

The shackles are indeed daunting. First speaker Matt Kondolf of U.C. Berkeley painted a stark picture of damage done to the ecosystem — the dams, reservoirs and levees controlling its spill from the Sierra to the ocean. Only one of nine rivers — the Cosumnes — runs free;only three of dozens of creeks have healthy populations of spring-run Chinook salmon while less healthy salmon venture forth from hatcheries that Kondolf likened to "methadone maintenance programs." Reservoirs in the Sacramento and San Joaquin River basins are so extensive they can now store more water than actually runs off. Real restoration of this system would require removing whole dams from the headwaters and whole cities from the floodplains.

Perhaps that's why conference organizers chose the theme of "rehabilitation," rather than restoration — a choice second speaker Jordan scolded them for. "Rehabilitation means fitting or refitting something out for use, it's so unspecific it doesn't mean very much," he said, "but everybody knows what restoration means, it means putting something back the way it was, going back to something better."

Whatever the word, putting it back the way it was, using the natural historic landscape and ecological processes as a guide, was the theme of speaker after speaker at the conference. Hydrologist Phil Williams donned an imaginary white coat and diagnosed the Estuary as suffering from many pathological conditions including blocking (dams), narrowing (channelizing) and hardening (levees) of the arteries (rivers), persistent bleeding (exports),flatlining of the rivers (no more peaks and pulses and floods), and anemia (inability to capture sediment). He called the purchase of floodplain lands without making provisions for creating flood flows "cosmetic restoration" and said it was time to retrofit California's "obsolete" water project infrastructure and rethink operation of the dams — many of which operate based on outdated 1940-50s policies and science. "It's time to free ourselves of the legacy of decisions made 60 years ago," he said, calling for serious evaluation of the potential to remove some major dams.

The power of dams and levees to shoot water straight through the Estuary, instead of allowing it to sit around for awhile, was the theme of the following talk, by U.C. Davis' Jeff Mount. Mount said it used to take weeks for water to move through the San Joaquin River system, and now it takes days — largely because the river has been separated from plains where it used to flood, meander and deposit sediments and nutrients. "The best restoration efforts done within the basin will be those that enhance residence times," he said, citing the productivity of the Yolo Bypass where water now floods 59,000 acres for two weeks instead of a few days, spurring growth of aquatic plants and animals and fattening fish.

When water sits around for awhile, it has more time to seep down and replenish groundwater aquifers and speaker Neil Dubrovsky of the U.S. Geological Survey argued that it's been a mistake to separate management of surface water from groundwater for so long. He reminded the audience that there's three times as much groundwater as surface water, and that the two were once part of an integrated hydrologic system in which groundwater was recharged by infiltration of stream flow and rainfall and in turn supported extensive wetlands along the axis of the Central Valley, as well as sustaining Delta streams during dry months. The valley's aquifers constitute an enormous storage compartment for fresh water (102 million acre feet of usable storage or more than twice the amount stored in reservoirs statewide). Dubrovsky suggested it was time to analyze and confront the long-term costs of groundwater problems caused by overpumping and agricultural drainage — land subsidence and contamination — and to explore storage of water in aquifers rather than new reservoirs, thus recreating the hydraulic connection between water above and below ground.

Next on stage was Stanford's Steve Monismith, who discussed the perils and the promise of using statistical models to predict how Estuary circulation and transport might respond to CALFED'S efforts to restore the Delta. Monismith advocated creation of a 21st century replacement for the Bay Model in Sausalito. This new three-dimensional Bay Model 2000 — to be housed in a network of desktop computers — would maintain accuracy by assimilating real time data from sensors throughout the system and could predict such things as phytoplankton dynamics resulting from creation of new shallow water areas in the Delta.

The creation of too much pavement in the Estuary watershed was Gary Binger's pet peeve. This speaker from the Association of Bay Area Governments described the challenges of getting 101 governments to reduce the amount of impervious surface causing urban runoff pollution,and to protect watersheds and stream corridors. Binger gave the Bay Area an environmental land use report card grade of "C-" — arguing that cities need to do much more to halt land- and water-wasteful sprawl with urban growth boundaries, to cluster new development, to promote urban infill, to increase transit-oriented development, and to stop zoning for jobs without providing housing. The latter has led to longer commutes and more pavement, hence more pollution.

Pollution caused by restoration was the surprise of the next talk, as the U.S. Geological Survey's Sam Luoma reminded the audience that one good thing does not always lead to another. He warned that removing dams or restoring marshes in areas with known deposits of debris from 1800s hydraulic gold mining might worsen the Estuary's already pervasive methyl mercury pollution.

Another potential negative impact from restoration is the increase of opportunities for exotic species to settle in. Disrupted soil, temporarily stripped of shading material,is ideal turf for invading riparian plants like *Arundo donax* (a habitat- and water-guzzling species commonly known as the "plant from hell"); likewise, salt ponds recently opened to the tides and newly created wetlands offer a blank slate for Atlantic cordgrass — a fast-spreading wetland plant currently making a folly out of many well-intentioned restoration efforts. According to U.C. Berkeley's Tom Dudley, the "build it and they will come" mentality must be tempered with planning to prevent unwanted vegetation. He also pointed out that the "stable hydrology" of our highly controlled water system reduces biodiversity and promotes invasions.

One of the strongholds of native biodiversity, at least in terms of fish, is Bay creeks, said speaker Rob Leidy of U.S. EPA. Compared to Central Valley creeks, Bay creeks have more diverse and healthy assemblages of native fish. Indeed native species dominated 75% of sites sampled by Leidy in 30 watersheds. Reasons for good native fish survival around the Bay may include fewer dams, diversions and reservoirs (major sources of exotics), less distance to the open ocean for migrating anadromous species, and the salt water at creek mouths —preventing movement of freshwater species and invaders between drainages. "These are all strong arguments for focusing restoration on Bay streams," said Leidy.

Restoration aimed at getting the most endangered fish, animals and plants back on their gills, feet and roots pervaded an information-packed panel on Day 2 of the conference. First up were fish. According to U.C. Davis' Peter Moyle, who reviewed the status of several declining native species, Delta smelt show no sign of recovery and nobody understands what's going on with green sturgeon. Numbers of splittail, salmon,longfin smelt and two other native fishes of concern have grown in the last five years as a result of an unusual series of wet years and the accompanying increased river flows. A return of the drought and high rates of diversion will likely cause their numbers to plummet again, however. "Nature has cooperated ever since the Bay-Delta Accord, and bought us some time. We need to make some serious commitments to conservation before the next drought," said Moyle. To help the fish, Moyle called for more and better floodplains, more natural hydrological regimes, improved access to upstream habitats, and prevention of further invasions by exotic species.

Prevention won't do much for natives of the Estuary's muddy and rocky bottom,however. According to Cal Fish & Game's Kathy Hieb, up to 90% of the benthic community is comprised of exotic species in many places, and no amount of habitat restoration can bring back the natives. In recent years, native zooplankton continued their decline dating back to the 1980s, she said, but Bay shrimp are on the rebound in part due to increased flows that aid shrimp migration and enhance nursery habitat. The ups and downs were nothing new to Hieb, who completed her talk by throwing up her hands and saying "There's no doubt that variability is the essence of the Estuary."

Owls and frogs could use a little more of that variability said the next speaker, at least in terms of habitats. Three quarters of the uplands once adjacent to the Bayshore have been farmed, grazed, logged, developed or otherwise destroyed, said San Jose State's Lynne Trulio, and today's levees now create a "hard edge around many wetlands, leaving virtually no transition to remaining uplands." Trulio zeroed in on the importance of this transition zone for the many birds, amphibians and terrestrial species (85% of special status species) that cross back and forth over the wetland/upland edge in search of food and refuge. "The hydrological situation on these transitional habitats is very complex and difficult to replicate. The problem is, we have almost no moist grassland, no vernal pools left to copy," she said.

The hard edge of many wetland restoration sites doesn't do much for floristic diversity either, according to speaker Brenda Grewell of U.C. Davis. As slide after slide of rare petals and foliage graced the screen, Grewell reminded the audience that plants offer both ecological and aesthetic benefits. Habitat degradation and fragmentation, and intruding exotic flora, have diminished many emergent marsh plant communities, and decimated species such as soft-haired birds beak, Suisun thistle and Mason's lilaeopsis. According to Grewell, restoration opportunities that "link tidal marshes to alluvial soils, seeps and drainages should be a high priority. The current tendency to create tidal marshes as indented pockets within levee systems, separated from the historic margins of the Estuary, will not support historic floristic diversity."

Next speaker Gary Page of the Point Reyes Bird Observatory warned that although tidal marsh and mudflat restoration in the Bay will help many birds, converting salt ponds to this end may not. "We can't turn back the clock for the Bay. Conversion of man-made salt ponds will have negative consequences for many waterbirds, birds that have no place else to go," said Page.

Far upstream where the wide shallows of salt ponds and Bay waters narrow into nine rivers and myriad tributaries, restoration efforts are often short-lived, said speaker Scott McBain of McBain and Trush. Here high flows are quick to damage or destroy the kind of patchwork attempts to restore individual gravel beds or river banks that have occurred without attention to the system as a whole. To better guide restoration, McBain listed ten attributes of healthy, alluvial, low-gradient, gravel-bed rivers in the Central Valley, among them variable stream flows; frequent movement of riffles and bars by moderate floods; periodic channel migration; access to a functional floodplain; and sediment transport at approximately the same rate as delivered by the watershed. These simple, quantifiable attributes evoke the historic fluvial processes that underpin the river system, according to McBain. Based on these attributes, McBain's recommendations for river rehabilitation ranged from creating more varied stream flows and establishing continuous riparian floodways to increasing coarse and reducing fine sediment supplies and storage.

Later, Joy Zedler from the University of Wisconsin, and several other speakers, described the critical follow-up task of monitoring the results of restoration efforts. Zedler's case in point was a 300-acre San Diego mitigation project called Sweetwater Marsh. In her evaluation of project success, Zedler looked at the degree to which compliance criteria had been met for three endangered species damaged by the development. Using remote sensing and satellite imagery as tools, Zedler examined habitat development over time and found that criteria for two species — the California least tern and salt marsh birds beak — had been met. Habitat for the light-footed clapper rail, however, had serious short-comings, namely coarse soil, low nutrient supplies, short vegetation, scale insect outbreaks and inadequate nesting habitat.

According to Zedler, lessons learned from the San Diego project pinpoint five ecosystem components that should not be ignored in restoration: anthropod predators (there were no beetles to prey on the scale insects); plant canopy structure; soil structure; soil nutrients and site-landscape interactions.

Another follow-up effort was described by Charles Simenstad from the University of Washington, who compared several different restoration projects of different ages in the Pacific Northwest to local control sites. Looking for a possible correlation between project age and fish utilization, he found that the numbers of juvenile Pacific salmon and a prominent sculpin generally increased in the older marshes.

Simenstad felt that although the promise of restoring tidal marsh ecosystems has increased over the years, efforts still suffer from the following pitfalls: "functional forcing" (restoring only one or two functions or habitats rather than a whole multi-functional ecosystem); "demand for instant gratification," (expecting marshes to mature in far less time than natural processes allow, and intervening to make things speed up, which is often counterproductive); and "maladaptive monitoring" (monitoring response without exploring the underlying ecological processes at work in the system.

As the conference progressed, speakers touched on myriad other topics ranging from restoring Delta islands, managing stormwater and working with wildlife-refuge neighbors to developing publicly palatable indicators of restoration success and coming to scientific consensus on ecosystem goals.

As engineer Jeff Haltiner of Philip Williams & Associates put it in the waning hours of the conference: "It's nice to be involved in the restoration movement, it's kind of messianic, religious... When it gets boring and mundane, that will be when it's successful, because it will be ingrained in the culture of the country."

-Ariel Rubissow Okamoto

VITAL STATISTICS
1996-99

PERSPECTIVE

Historical Changes to the Bay-Delta Watershed:

Implications for Restoration

G. Mathias Kondolf
University of California, Berkeley

Over the last century and a half, the watershed of the San Francisco Bay-Delta has been altered to an extent not commonly appreciated. Populations of native fishes (including an estimated 2-3 million Chinook salmon) that formerly inhabited the system have declined, with many races extinct or nearly so. Overfishing and competition from introduced species have been important factors in the declines. Moreover, the geomorphic, hydrologic and ecological processes in the watershed that formerly supported these native fish species have been fundamentally changed by dams, diversions, groundwater pumping, conversion and filling of floodplain and intertidal wetlands, gold and gravel mining, levees, artificial bank protection, pollution, and land-use changes in the watersheds draining to the rivers, Delta, and Estuary.

Reservoir storage capacity in the Sacramento-San Joaquin system now totals 30 million acre-feet, with storage equivalent to over 80% of the runoff in the Sacramento River basin and nearly 140% of the San Joaquin River basin runoff. As a result, frequent floods (important for maintaining channel form and habitat) have been eliminated or drastically reduced on many rivers. As documented by the Bay Institute, tidal wetlands in the San Francisco and Suisun Bays have been reduced to only 8% of their former extent. Intertidal wetlands in the Delta have been diked off so thoroughly that of the 400,000 acres that existed in 1850, only 8,000 remain: only 2% of their original extent. Similarly, 90% of the riparian forest and riparian wetlands of the Sacramento Valley have been cleared, filled, or otherwise eliminated (Bay Institute 1998).

It is essential that we understand the nature and extent of these changes to develop restoration goals and to understand constraints upon what we can realistically achieve, even in a massive restoration program (Kondolf and Larson 1995). For example, we understand that extensive flooding was an important process in maintaining habitat for salmon and other native fish, but we cannot realistically move large cities from the floodplain, nor is it likely that we will remove most existing dams. However, it may be possible to restore floodplain flooding along some rivers and streams, permitting natural processes to shape channel and floodplain habitats. Thus, we should prioritize acquisition of land or flooding/erosion easements along rivers that still flood (i.e., rivers that have not been so dammed that they no longer have high flows). Restoration of floodplain functions in these reaches can also reduce flooding pressure elsewhere (Healey et al. 1998).

To be effective and sustainable, restoration must be based on a real understanding of geomorphic and ecological processes, which can inform restoration goals and choice of implementation strategy. Recognizing that uncertainty is unavoidable in light of our limited understanding of the functioning of the system, an adaptive management approach has been adopted by the CALFED ecosystem restoration program, emphasizing that restoration actions can be taken that serve to increase our understanding of the system's responses (Healey et al. 1998) (Kondolf, SOE, 1999).

➤ MORE INFO?
www.ced.berkeley.edu/landscape/kondolf

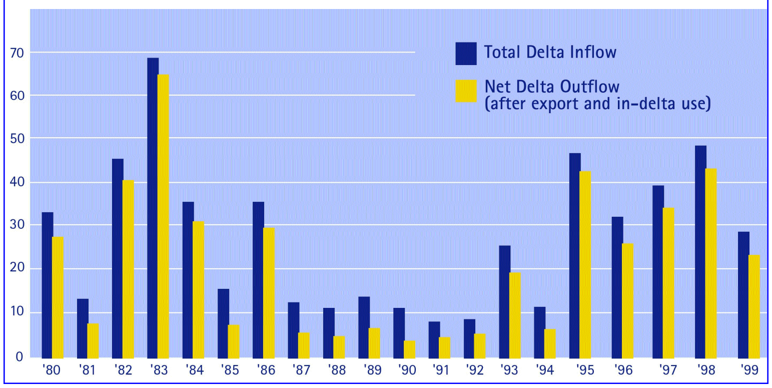
FLOWS

Recent Inflows

Normal or above normal rainfall has meant improved Delta inflows in recent years. Inflows to the Delta and Estuary were 39.8 million acre feet (MAF) in water-year 1997 (October 1,1996 - September 30,1997),48.5 MAF in 1998 and 28.3 MAF in 1999. Delta outflows were 33.7 MAF in 1997,43.5 in 1998 and 22.4 in 1999 (DWR).

➤ MORE INFO? dfriend@water.ca.gov

Freshwater Flows to the San Francisco Estuary, 1980-96
in millions of acre feet



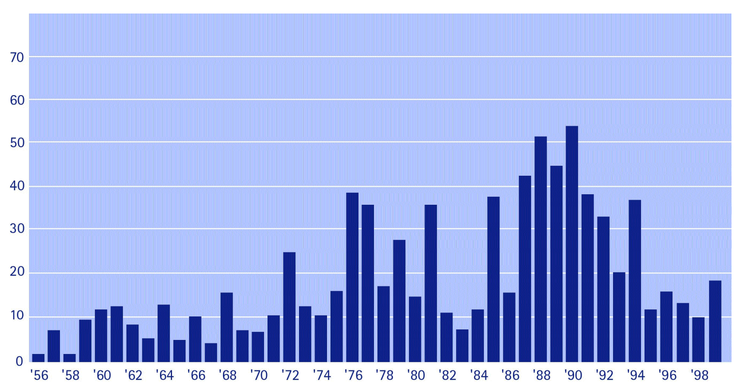
Source: DWR

Diversions for Beneficial Use

Water is diverted both within the Delta and upstream in the Estuary's watersheds to irrigate farmland and supply cities. In-Delta exports have largely remained within the range of 4 to 6 MAF per year since 1974,but the percent of Delta inflow diverted can vary widely from year to year. In water-year 1997,5.1 MAF were diverted, 4.8 MAF in 1998 and 5 in 1999. The mean percentages of total Delta inflows diverted were 13% in 1997, 10% in 1998 and 18% in 1999 (DWR).

➤ MORE INFO? dfriend@water.ca.gov

Amount of Inflow Diverted, 1956-99
Mean percent of inflow diverted



Source: DWR

Water Recycling

Recycled water can be used to meet many of the needs of cities, industries and agriculture, helping to reduce demand on the Estuary's limited water supply. Much more information documenting recycled water use was available for the last *State of the Estuary* report (1993-1998) than for the most recent period covered by this report. Experts say conditions have been wet enough in recent years to dampen enthusiasm for recycling projects. In general,however, Southern California remains far ahead of the Bay Area in water recycling efforts. But 25 Bay Area communities currently have or plan water recycling projects. The Bay Area Regional Water Recycling Program's Master Plan calls for recycling 125,000 acre-feet of water per year in the Bay Area by 2010 and about 240,000 af/year by 2025 to help create a reliable, drought-proof water supply.

➤ MORE INFO? www.recyclewater.com.

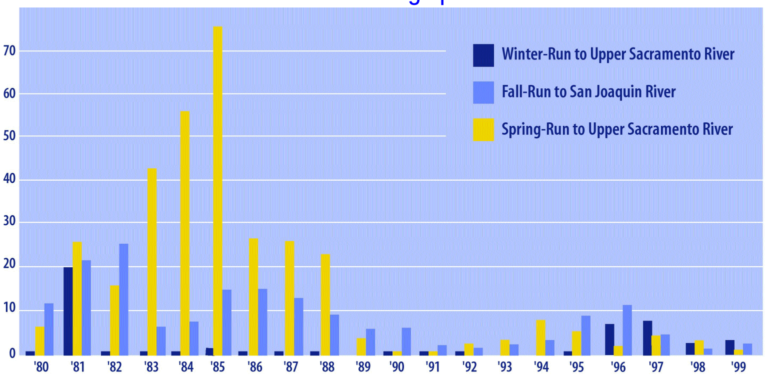
FISH

Central Valley Salmon

Most populations of Central Valley Chinook salmon seem to be holding relatively steady, with increases for several protected runs. Central Valley salmon occur in four discrete runs — winter-run, spring- run, fall-run and late fall-run (run refers to the season in which adults return to their native streams to spawn). The winter-run Chinook, with the lowest population, has been listed as both a state and federal endangered species since 1994. Although the 1997 return of winter-run was only 841, the population rebounded somewhat to 2,612 in 1998 and 3,208 in 1999, the highest return since 1985. The next most sensitive stock, the spring-run, was state listed as a threatened species in 1998 and federally listed in 1999. The spring-run population jumped from a five-year low of 5,312 in 1997 to 31,594 (the highest on record), then fell to 10,134 in 1999. Sacramento fall-run are the most abundant Chinook stock, with 308,674 returning in 1999. The 1999 San Joaquin fall-run return of 24,459 was also above the 1967 to 1991 average annual return of 21,000. The "late" fall-run (distinct from fall-run) Central Valley Chinook population was 4,578 in 1997, 12,796 in 1998 and 8,683 in 1999 (Kano, Pers.Comm., 2000).

➤ MORE INFO? bkano@dfg.ca.gov.

Salmon Runs of Concern
in thousands of adult fish returning spawn



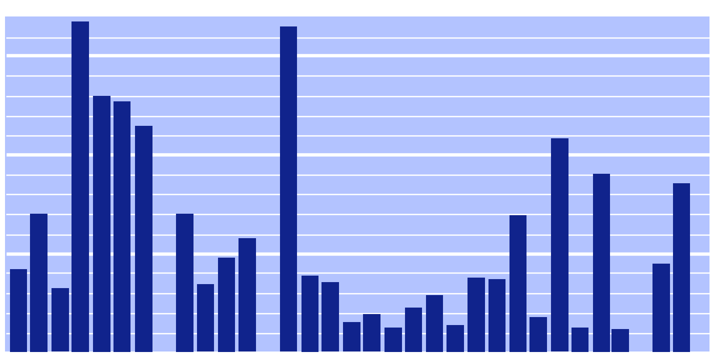
Source: CDFG

Delta Smelt

The Delta smelt, a 2-3 inch-long, translucent fish with a silvery blue sheen, was listed as a state and federal threatened species in 1993. Historically one of the most common species in the Estuary, the population declined dramatically in the early 1980s. Delta smelt are considered environmentally sensitive because they typically live for one year, have a limited diet, and reside primarily in the interface between salt and fresh water. In addition, females produce only 1,000 to 3,000 eggs, and the planktonic larvae have a low survival rate. Possible reasons for the Delta smelt's decline include reductions in outflow, high outflows (which push them too far down the Estuary), entrainment losses at water diversions, changes in food type and abundance, toxic substances, disease, competition, predation and loss of genetic integrity. The 1998 Fall Midwinter Trawl index, 420, was the highest in three years, and the 1999 Summer Townet index, 11.9, was the highest since 1994, although it was still below a pre-decline average of 20.4. The 1999 fall midwater trawl index was 864, the third highest in 19 years. In the spring of 1999, delta smelt spawned primarily in the Delta and remained there for several weeks, causing high entrainment levels at the State Water Project and the Central Valley Project and reduced water exports at both facilities for over a month (McIntire, Pers. Comm., 2000; Rockriver, Pers.Comm., 2000).

➤ MORE INFO? 8mcintir@delta.dfg.ca.gov

Delta Smelt Abundance Index, 1967-99
Fall Midwater Trawl



Source: CDFG

Longfin Smelt

Experts predicted a large longfin smelt population in 1997 due to very good recruitment in 1995 and extremely high outflow in winter 1997, when the 1995 year class spawned. However, longfin smelt abundance, as measured by the CDFG fall midwater trawl survey, only reached an index of 676, just slightly higher than indices during the 1987-1992 drought. This severe decline led to speculation that many recruits had washed out to and reared in the Gulf of the Farallones. However, age-1 longfin smelt indices in 1998 were also very low, suggesting poor survival for the 1997 year-class. In 1998, longfin smelt abundance increased substantially to an index of 6,658, mostly comprised of young-of-the-year. The 1998 progeny resulted from 1996 year class spawners, the first even-year recruits from a post-drought wet year. Historically, strong year classes alternated years and were a function of outflow during the early larval period. Poorer than expected longfin smelt abundance in 1997, together with good flows in 1996 and better flows in 1998 allowed even-year classes to build on one another and become dominant (Baxter, Pers.Comm.,2000).

➤ MORE INFO?rbaxter@delta.dfg.ca.gov

Splittail

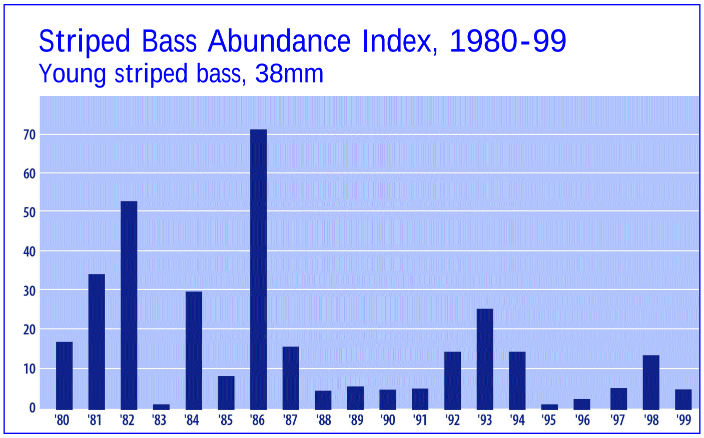
The Sacramento splittail appears to have benefited from the recent series of wet years (Moyle, SOE, 1999). Populations of the silvery-gold minnow, found only in Central Valley rivers and the Delta, had declined sharply in recent years as a result of drought, dams and diversions reducing access to spawning habitat. The splittail was listed as threatened under the federal Endangered Species Act in early February 1999. Splittail abundance in 1997 was poor (CDFG fall midwater trawl survey index = 1.1), contrary to predictions. Though dramatic flooding occurred in January 1997, the lack of subsequent rains resulted in dry conditions during the March-April peak spawning period. In contrast, high and persistent outflows in 1998 led to a record high fall midwater trawl survey total index of 282. Young-of-the-year (YOY) made up 85% of the total index. Though not record indices, YOY indices from the Delta Outflow-San Francisco Bay Study midwater and otter trawls reached levels comparable to 1995, again indicating strong recruitment for 1998 (Baxter, Pers.Comm.,2000).

➤ MORE INFO? rbaxter@delta.dfg.ca.gov

Commercial Fisheries

Although the spawning biomass of Pacific herring — by far the Bay's largest commercial fishery- was the third highest on record in 1996-1997, it plunged to 20,000 tons in 1997-1998 due to low ocean productivity attributed to 1997's El Niño, and has not recovered. The spawning biomass in 1998-1999 was 39,500 tons, and despite good ocean productivity, preliminary indicators are that the 1999-2000 spawning biomass will be below the long-term average, which stands at 54,929 since 1978-1979 (Watters, Pers.Comm., 2000).

➤ MORE INFO?dwatters@dfg2.ca.gov



Source: CDFG

Striped Bass

The population of striped bass, an important sport fishing species, shows little sign of improvement. In 1999 the indices for both the mid-summer townet survey and the fall midwater trawl survey indicated that young-of-the-year striped bass abundance is considerably lower than in the 1970s and early 1980s. Before 1995, high indices were generally associated with wet years and low indices with dry years. However, since 1995, both indices have been the lowest on record even though these were wet years. The 1999 townet survey index was 2.2, making the fifth consecutive year that the index has been below 10. The 1999 fall midwater trawl index of 541 was only 44% of the 1998 index of 1,224, but similar to the years 1995-1997, when the index varied from 392 to 568. Prior to 1995, only five other years (all dry or critically dry) had fall indices below 1,000 (Gartz, Pers. Comm.,2000).

➤ MORE INFO?Rgartz@delta.dfg.ca.gov.

See also page 34 for more information on endangered fish.

INVASIVE SPECIES

Green Crabs

The green crab *(Carcinus maenas)* was first found in South San Francisco Bay in the early 1990s, and has spread north at least as far as the Carquinez Strait. Its distribution is limited by salinity: crabs have been collected from water ranging from 7.5-31 parts per thousand (ppt) salt to water, but few have been collected from water with less than 10 ppt. On the west coast, green crabs are now found as far north as British Columbia (Hieb, Pers.Comm., 2000). In contrast to its wide native range along the Atlantic coast of Europe, in western North America the green crab is restricted to low energy, soft substrate habitats.

In a nine-year study of green crabs in Bodega Bay, Grosholz, et al. found that in contrast to their slow growth rates in Europe, green crabs grew rapidly and reached sexual maturity in their first year. Over the course of the nine-year study, the green crab significantly reduced the abundance of 20 invertebrate species, and within just three years of being introduced, reduced densities of native clams and native shore crabs by 5-10%, including that of the shore crab *Hemigrapsus oregonensis*, a common inhabitant of the lower South San Francisco Bay. The study found no "bottom-up" effects on the food web that would impact shorebirds; however, such effects may occur as the geographic range and local effects of the green crab increase (Grosholz, et al. 2000).

➤ MORE INFO? khieb@delta.dfg.ca.gov or tedgrosholz@ucdavis.edu

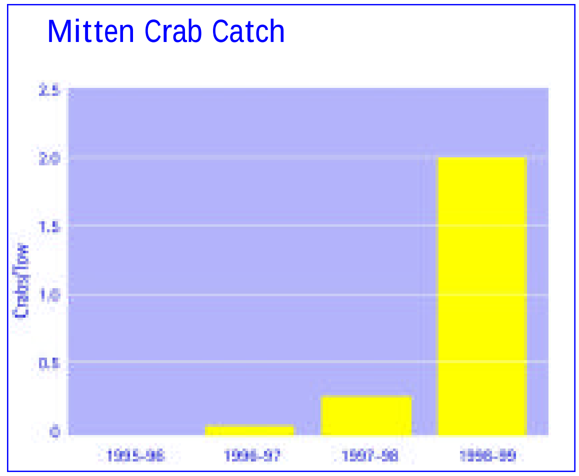


Figure 1. Annual (October-March) catch per tow of adult Chinese mitten crabs from CDFG's San Francisco Bay Study otter trawl survey, 1995-96 to 1997-98. All female crabs >34 mm carapace width (CW) and male crabs>39 mm CW were considered to be adult. Source: CDFG

Chinese Mitten Crabs

The Chinese mitten crab *(Eriocheir sinensis)* was introduced to South San Francisco Bay in the late 1980s or early 1990s; the 1990s saw a rapid increase in its population and expansion of its distribution. By 1998, the mitten crab was widely distributed in the Sacramento-San Joaquin Delta and the Central Valley. In 1999, the population of adult crabs decreased somewhat, and distribution was more restricted than in 1998, especially in the San Joaquin River. Although initially the mitten crab population in California increased exponentially, it is expected to eventually decrease and remain at low or stable levels for some time — in the "boom and bust" style of many introduced species (Hieb, Pers.Comm., 2000).

Migrating adult crabs have interfered with fish salvage activities at pumping facilities in the south delta. In fall 1996, the federal water project collect-

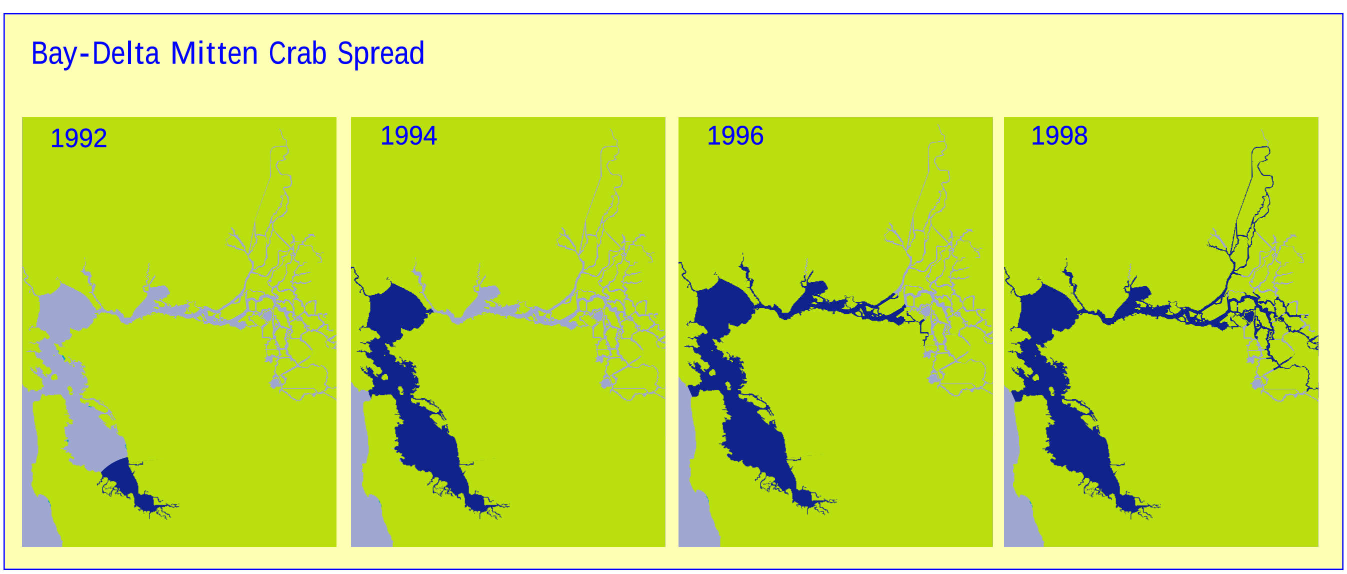


Figure 2. Distribution of the Chinese mitten crab in the San Francisco Estuary and its watershed, 1992, 1994, 1996, and 1998. Solid blue area or lines indicates presence of the crab. Source: CDFG

ed less than 100 crabs at their fish salvage facility. In fall 1997, they collected approximately 30,000 crabs; in fall 1998, at least 775,000 crabs; and in fall 1999,approximately 90,000 crabs.

Mitten crabs also steal bait from sport anglers and bay shrimp from commercial trawl nets, and clog PG&E power plant cooling water systems in the western delta. The crab's burrowing is thought to weaken levees and banks, but no damage attributable to the crab has been confirmed. A National Management Plan for mitten crabs has been submitted to the Aquatic Nuisance Species Task Force.

➤ MORE INFO? khieb@delta.dfg.ca.gov

Pike

Northern pike, native to Canada and the Midwest, were illegally planted in the 85,000-acre-foot Lake Davis reservoir around 10 years ago. In 1997, the state Department of Fish and Game treated the lake with Rotenone to try to prevent the voracious fish from escaping into the Sacramento River and eating endangered salmon, but the treatment temporarily compromised local water supplies and an important local fishery. In May 1999, the pike reappeared. Since then, biologists have pulled over 250 pike from the lake, in an effort to prevent the population explosion seen between 1994 and 1997. After fish surveys revealed that 95% of the pike were inhabiting Mosquito Slough, a shallow weedy channel leading into the lake, a 250-foot wide, 20-foot deep net was installed across the mouth of the slough to trap the pike and prevent them from entering the lake (Martarano, Pers.Comm.,2000). The pike have not been found outside of Lake Davis during the last few years (Moyle, Pers. Comm.,1999). A Lake Davis Coalition was formed and released a management plan in February 2000 recommending trying physical barriers, electric shocks, underwater explosions, and even fishing derbies to control the pike.

➤ MORE INFO? smartara@dfg.ca.gov

Asian Clams

The Asian clam *Potamocorbula amurensis* has continued to be the dominant benthic organism in the North Bay and is also dominant in the Bay's southern extreme during most years. The return of freshwater flows has resulted in a seasonal decline of the bivalve throughout the North Bay in winter, followed by peaks in density after reproduction in spring and fall. A substantial increase in phytoplankton biomass was seen in spring 1998 in central San Pablo Bay. The only benthic station that is routinely sampled in San Pablo Bay, DWR's station D41A,shows the phytoplankton bloom occurred during the annual drop of *P. amurensis*, thus supporting the supposition that declines in phytoplankton are a result of overgrazing by *P. amurensis* (Thompson, Pers. Comm.,2000).

Giant Reed

Giant reed *(Arundo donax)* was originally introduced into California by the Spanish in the late 1800s for erosion control along drainage canals, and since then this "plant from hell" has become a huge problem along riparian areas around the Bay. The reed spreads when pieces of the plant break off and wash downstream. The pieces—from either the stalk or roots—can establish themselves wherever they are deposited. The reed guzzles water and can smother native riparian vegetation. It is also highly flammable. In 1997, it had been spotted in the Russian River, Napa River, Sonoma Creek, and San Pedro Creek. Just a few years later, it can be found from Sacramento tributaries to small urban streams throughout the Estuary. Eradication and education programs are underway.

➤ MORE INFO? team_arundo@ceres.ca.gov

Courtesy Ron Unger

Shimofuri Goby

The shimofuri goby *(Tridentiger bifasciatus)* is a recent invader of the Estuary, and probably arrived in ballast water. The goby was first collected in 1985 in Suisun Marsh and has spread rapidly throughout the Estuary. In Suisun Marsh,the goby spawns repeatedly from March through September, typically depositing 9,000 – 19,000 adhesive eggs on a hard, protected surface. The male goby guards the eggs until they hatch,which can take five to ten days depending on water temperature. Experiments show that the shimofuri goby can tolerate a wide range of temperatures and salinities, which means it is capable of expanding its range into that of the endangered tidewater goby *(Eucyclogobius newberryi)*. In the laboratory, shimofuri gobies are aggressive toward tidewater and yellowfin gobies (Matern, SOE poster,1999).

➤ MORE INFO? samatern@ucdavis.edu

For more information on invasives see pp. 54-55 .

WETLANDS & WILDLIFE

Wetlands

Only 3-4% of the Bay-Delta's historic wetlands remain intact today. Fewer wetlands and riparian zones have been protected through acquisition since 1996 than in the prior three year period, falling from 18,677 acres in 1996 to 10,983 in March 1999. During the earlier period the vast majority of reported acquisitions were baylands (namely the unusually big purchase of almost 10,000 acres of North bay salt ponds),whereas the more recent period included much larger acreages of riparian zones and floodplain (6,106 acres in the San Joaquin River Wildlife Refuge alone). Acres protected by perpetual conservation easements over private lands in the Central Valley and Suisun Marsh grew from 67,292 to 75,000 acres between 1996 and 1999.

On the restoration front, the number of acres actually restored or enhanced grew from at least 8,137 acres in 1996 to at least 13,656 acres of wetlands in March 1999 (note:acquisition and restoration acreages overlap). The number of restoration projects in the planning stages, many with no guarantee of construction funding, also swelled, from at least 12,693 acres in 1996 to 19,109 acres in March 1999. Where most projects might have been undertaken as mitigation for development of wetlands in the past, the vast majority of current projects are aimed at the health of the ecosystem. The acreage of wetlands restored outpaced that lost — see p. 67. Finally, programs providing incentives to individual landowners to flood their land for seasonal waterfowl and wetlands continued to grow — enhancing or restoring over 90,000 acres as of 1999 —but did not keep up with demand (the owners of at least 47,000 acres still want to sign up) (Appendix A, SFEP, 1999).

➤ MORE INFO? bayariel@earthlink.net

California Clapper Rail

While numbers of the endangered California Clapper Rail *(Rallus longirostris obsoletus)* had dropped as low as 300-500 birds by 1991, recent surveys indicate the rail's Bay population may be close to 1,200 and fairly evenly divided between the North and South Bays. However, heavy rains in the winter of 1997-1998 may have caused some declines in the North Bay, as residual high water, particularly along the North San Pablo Bayshore impacted nesting success (Albertson and Evens 1998). See also p. 46.

➤ MORE INFO? jevens@aol.com

Least Terns

While endangered least terns continue to nest at the Alameda Naval Air Station, re-use of the station may not bode well for the terns, with human disturbance and non-native predators on the rise. Although the number of pairs of terns using the base remains stable, the number of successful fledglings has decreased by a third since 1997. Further north, the number of terns at the Southern Power (formerly PG & E) cooling ponds in Pittsburgh has tripled, with 11-12 pairs counted at the site this year. Southern Power is continuing PG & E's voluntary monitoring program at the site (Collins, Pers. Comm.,1999). Since most nesting attempts at the Oakland Airport in the past few years have failed (probably due to predation by feral cats and the non-native red fox), the airport is no longer required to monitor terns or manage predators (Feeney, Pers. Comm.,1999).

California Least Tern Nesting

Alameda Naval Air Station

Year	Maximum Number of Pairs	Maximum Number of fledgings
1976	10	NA
1977	45	NA
1978	80	13
1979	40	NA
1980	77	8
1981	74	103
1982	70	0
1983	3	1
1984	47	10
1985	53	60
1986	53	88
1987	59	97
1988	67	87
1989	75	93
1990	99	108
1991	112	144
1992	130	221
1993	128	210
1994	138	206
1995	150	73
1996	208	233
1997	244	316
1998	243	90

Salt Marsh Yellow Throat

The salt marsh yellowthroat (*Geothlypis trichas sinuosa*), also known as the San Francisco yellowthroat, is a subspecies of the common yellowthroat. The salt marsh yellowthroat is hardly common,however, and is a state Species of Special Concern and a federal Species of Management Concern. Surveys in 1997 estimated 0.7 yellowthroats per hectare of marsh studied (or about 28 birds per 100 acres). Between 5,700 and 10,600 salt marsh yellowthroats may be breeding in available tidal marshes, and an additional unknown number in brackish and freshwater marshes. However, salt marsh yellowthroats were not common in marshes other than those in Suisun Bay; in some marshes, no yellowthroats were found.

➤ MORE INFO? nadavnur@prbo.org

Salt Marsh Song Sparrows

The reproductive success of salt marsh song sparrows was lower in 1997 and 1998 than in 1996. In 1998,nest success (the probability that a nest fledges at least one young) was half of what it was in 1996,a trend of concern. Preliminary data for 1999 indicate continued low nesting success, with flooding the major cause of nest failure. Estimated numbers of Alameda song sparrows range from 3,700-8,100; for the Suisun song sparrow from 23,000-50,000;and for the Samuel's song sparrow from 20,000-44,000 (Nur, Pers. Comm., 1999). Both salt marsh song sparrow and salt marsh yellowthroat densities were greater in marshes with more channels, whether those channels were manmade or natural. While song sparrow density does not appear to be positively correlated with any one species of plant, yellowthroat densities were positively correlated with the percent cover of Scirpus (including bulrushes and tules), peppergrass, and cattails (Nur 1997).

➤ MORE INFO? nadavnur@prbo.org

Peregrine Falcons

With the ban of DDT and extensive captive breeding efforts, the Bay's lost peregrine falcon population has begun to recover. Peregrine falcons commonly prey on ducks and waterbirds, and are thus a part of the estuarine food web. By the late 1980s and early 1990s, the Bay Bridge had two breeding pairs, and peregrines were wintering on all of the Bay bridges, even the Bay Bridge toll plaza. This year, there were confirmed nesting attempts on almost all of the bridges, meaning that at any given time, approximately 7 pairs of peregrines make the Estuary their home. The U.C. Santa Cruz Predatory Research Group has been removing young from the bridges when they begin to fledge to prevent them from drowning or being hit by cars (which often happens),and releasing them elsewhere around the state (Bell, Pers. Comm.,1999).

➤ MORE INFO? dbell@sfbdo.org

Riparian Brush Rabbit

A subspecies of brush rabbit, the riparian brush rabbit *(sylvilagus bachmani riparius)*, is considered the most critically endangered species in the state, with less than a few dozen rabbits remaining. Endemic to California and weighing only 1.5 pounds, the rabbit was once common along the middle part of the San Joaquin River and tributaries, extending as far upstream as the riparian forests did. The remaining members of this subspecies are largely confined to Caswell State Park, along the San Joaquin,where 1997 floods probably lowered their already small numbers(Faubion; Pers. Comm.,1999 & Williams; Pers. Comm.,1999).

➤ MORE INFO? rfaubion@mpusbr.gov

Harbor Seals

Harbor seal *(Phoca vitulina)* numbers in the Bay have remained fairly stable over the past decade. Depending on the season—pupping, molting, or winter—they can be found in large numbers at one of three haul-out sites. During pupping season (March-May),harbor seals are most plentiful at Mowry Slough,where a high of 240 seals was counted during 1995-1997. In 1998,numbers dropped to 201. In the winter months, the seals are most plentiful at Yerba Buena Island, when Pacific herring *(Clupea pallasi)* are spawning in the Bay. In winter 1998, researchers counted 296 seals at Yerba Buena,slightly up from 1995's 242. Castro Rocks, a chain of rock clusters just south of the Richmond Bridge, is used year round, although more seals use the rocks during pupping and molting season (June-August). In the 1995 molting season, researchers counted 161 seals on the rocks. Numbers dropped over the next three years, reaching as few as 96,but by 1999 the count had rebounded to 141. Additional information is available for the Castro Rocks population,where researchers from San Francisco State University have been collecting baseline data for the past year and a half to help minimize impacts on the seals from seismic retrofit work scheduled for the Richmond Bridge in 2000. Harbor seals have been known to abandon a site if human disturbance is too great. (Green, Pers. Comm.,1999).

➤ MORE INFO? seals@sfsu.edu

Salt Marsh Harvest Mouse

The status of the Bay's endangered salt marsh harvest mice *(Reithrodontomys raviventris)* hasn't changed much over the past few years. Small and very small populations (a few mice per acre) can still be found in many locations around the Estuary in habitats that are marginal at best;the conversion of salt marsh to freshwater marsh in the South Bay poses a continuing problem for the mice (Shellhammer, Pers.Comm.,2000). In the North Bay at Suisun Marsh,mitigation for water project impacts requires state and federal agencies to conduct surveys of the salt marsh harvest mouse populations every three years. Seven set-aside areas in the marsh and the Peytonia Slough Ecological Reserve were surveyed during August and September 1998. The salt marsh harvest mouse appeared to have survived the extensive flooding of early 1998 while the western harvest mouse and house mouse did not. Trapping success was greatest at the Benicia Industrial unit, where 18 mice were captured in one month (Finfrock, *IEP Newsletter* Fall 1998).

➤ MORE INFO? shellhammer@biomail.sjsu.edu or pfinfroc@water.ca.gov

WATER & SEDIMENTS

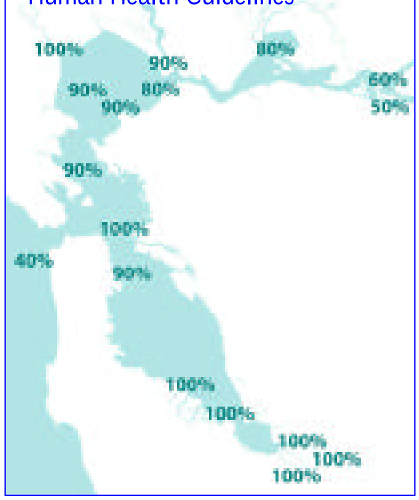
Overall Contaminant Conditions

The level of contamination in the Estuary today is high enough to impair the health of the ecosystem, even though some contaminants are clearly reduced from peak levels seen in earlier decades. As a whole, the Estuary can be described as moderately impaired. Indications of impairment include the toxicity of the water and sediment samples; the frequent presence of contaminant concentrations exceeding water, sediment and fish guidelines; and altered communities of sediment dwelling organisms. Overall, sites in the lower South Bay, the Petaluma River mouth, and San Pablo Bay are more contaminated than other sites. Contamination in the Central Bay is lower primarily due to mixing with relatively clean ocean water. Of all the contaminants measured by the Bay's Regional Monitoring Program, results suggest that those of greatest concern are mercury, polychlorinated biphenyls (PCBs), diazinon and chlorpyrifos (two pesticides). Also of concern are copper, nickel, zinc, DDT, chlordane, dieldrin, dioxins and polyaromatic hydrocarbons (PAHs). Work outside the RMP suggests that selenium is also a big concern (RMP, 2000).

➤ MORE INFO? www.sfei.org

PCBs in Water 1993-98

Percentage of Samples Exceeding Human Health Guidelines



Source: RMP

Percent of Bay Samples Meeting Water Quality Objectives*

	1994	1995	1996	1997	1998
Chromium	94	91	93	85	82
Copper	83	85	88	90	97
Mercury	79	80	87	67	75
Nickel	83	83	85	81	84
Lead	96	94	96	90	92
Selenium	100	100	100	97	99
Zinc	96	98	99	92	92
PAHs	61	69	53	59	25
Diazinon	93	100	94	100	100
Dieldrin	80	96	94	55	87
Chlordanes	100	93	84	87	89
DDT	98	92	90	88	91
PCBs	7	13	8	19	20

*Bay data from Regional Monitoring Program, SFEI 2000. Data from 1998 are preliminary.

Harmful Chemicals in Estuary Fish

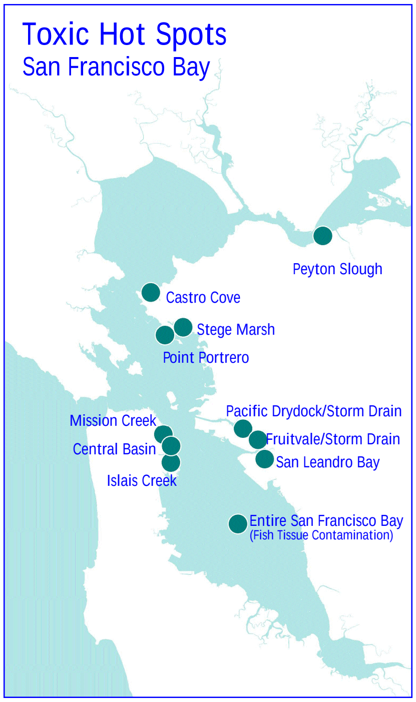
Estuary fish contain several types of contaminants at levels high enough to raise concern for the health of both the humans and wildlife consuming them, and even for the health of the fish themselves. Fish contamination guidelines referred to as "screening values" have been developed for the Estuary by the S.F. Estuary Institute's Regional Monitoring Program following the guidance of the U.S.EPA (exceedance of the values indicates potential human health concerns). In 1997, mercury and PCBs exceeded screening values for over 50% of the samples tested from the Bay. Researchers also tested a small number of fish samples for dioxins, and all seven of these samples exceeded the dioxin screening value. Screening values for DDTs, chlordanes, and dieldrin were exceeded in 15-37% of samples tested. Organic contaminants such as PCBs and pesticides were highest in white croaker and shiner surfperch, while mercury was highest in striped bass and leopard shark. Fish from the Oakland harbor contained significantly higher contaminant concentrations than those from other locations. Throughout the Bay, concentrations of PCBs, chlordane, dieldrin and DDT were lower in 1997 than 1994. Continued monitoring will be required to establish whether the declines observed are real indications of declining masses of contaminants or due to variation in other factors (RMP, 2000). Farther upstream, the Sacramento River Watershed Program began monitoring fish contamination in the river in 1997. White catfish from the Sacramento River exhibited relatively high mercury concentrations. Rainbow trout from the northern Sacramento River had the lowest mercury concentrations among the species sampled, and relatively low concentrations of organic contaminants (Davis et al., SOE Poster, 1999).

➤ MORE INFO? www.sfei.org

Toxic Hot Spots in Bay Sediments

Sediment quality screening of 127 sites in the Bay—conducted as part of the State Water Resources Control Board's Bay Protection and Toxic Cleanup Program—identified a number of sites as candidate toxic hot spots (see map). Screening involved the use of reference sites to establish toxicity thresholds, followed by laboratory toxicity tests, in which amphipods and sea urchin embryos were exposed to field-collected sediment samples. Researchers then revisited sites producing toxic samples for additional toxicity testing, chemical analysis, and evaluation of infaunal benthic communities. Preliminary investigations of sources and causes of observed toxicity were undertaken at a few candidate sites, indicating increasing adverse biological effects associated with increasing sediment concentrations of numerous covarying chemicals, including pesticides, metals, PCBs, PAHs, hydrogen sulfide and ammonia. Results (TIE) implicated trace metals as probable causes of toxicity at two sites, one in the South Bay and one in Suisun Bay (Hunt et al.,1998). Many of the most highly polluted sites were located near urban creeks and storm drains. (Hunt et al.,SOE Poster, 1999).

➤ MORE INFO? jwhunt@ucdavis.edu



Linking Pollutants to Biological Effects

The developed world has invested billions of dollars in waste treatment since the 1970s, however, changes in ecological or biological responses are rarely associated with reductions in metal pollutants. Researchers examined this association in a novel,23 year, time series of environmental change from a San Francisco Bay mudflat located 1 km from the discharge of a suburban domestic sewage treatment plant. Samples of surface sediment, the bioindicator clam *Macoma balthica* (which feeds on material attached to sediments),and metals loading data were used to establish links between discharge, bioaccumulation,and effects. Mean annual silver concentrations in *M.balthica* were 106 parts per million (ppm) in 1978 and 3.67 ppm in 1998. Concentrations of copper declined from 287 ppm in 1980 to a minimum of 24 ppm in 1991. Declining copper bioaccumulation was strongly correlated with decreasing copper loads from the plant between 1977-98. Relationships with bioaccumulation and total annual precipitation suggested inputs from non-point sources were most important in controlling zinc bioavailability during the same period. Reproduction of *M.balthica* in this metals-enriched environment persistently failed between the mid-1970s and mid-1980s, but recovered after metal contamination declined. Other potential environmental causes such as food availability, sediment chemistry or seasonal salinity fluctuations were not related to the timing of the change in reproductive capability. The results establish an associative link suggesting it is important to further investigate the chemical interference of copper and/or silver with invertebrate reproduction at relatively moderate levels of environmental contamination (Hornberger et al.,SOE Poster, 1999).

➤ MORE INFO? mhornber@usgs.gov

Contaminants in Coots

Though research shows that Bay Area water birds with diets high in animal foods are exposed to potentially health impairing trace elements, those with herbivorous diets have been less thoroughly examined. Researchers measured the concentrations of trace elements in the livers and the esophageal contents of an herbivorous water bird, the American coot *(Fulica americana)* to compare levels of contaminant exposure among different locations in the Bay system and with other water birds. They collected a total of 39 coots from four sites: Napa River and Mare Island Strait in the north, Berkeley in the middle, and Coyote Creek in the south. Livers of Berkeley samples differed significantly from those of Napa River and Mare Island Strait by their greater concentrations of arsenic and boron and lower concentrations of copper, but they seemed to be within normal ranges for birds. Otherwise the concentrations of trace elements in the livers did not differ among sites. Ingesta samples from Berkeley differed from the other sites because they tended to be higher in aluminum, vanadium,and zinc. In contrast to waterfowl,livers from the herbivorous coots in San Francisco Bay showed little exposure to cadmium,mercury, lead or selenium. Coot ingesta showed few samples with measurable levels of cadmium,mercury or selenium and had low levels of lead. The herbivorous diet of coots may shield them from exposure to such elements. However, high levels of vanadium were present in coot livers and ingesta from all four sites, suggesting adaptation to this known toxin (Hui,SOE Poster, 1999).

➤ MORE INFO? cliff_hui@usgs.gov

For further information on contaminants, particularly issues related to habitat restoration, see pp. 56-59.

PERSPECTIVE

Porter-Cologne at Age 30

Lawrence P. Kolb, S.F. Bay Regional Water Quality Control Board

The Porter-Cologne Act is California's basic law for water. It created the current structure for the State and Regional Boards, and defined much of the way California regulates water quality and quantity. It's been 30 years since the act was passed in 1969, a good time to review how well it has worked.

Passage of the Porter-Cologne thirty years ago directed the regional water quality control boards to regulate pollution, and greatly expanded their powers. One key enforcement element added was a provision that allowed regional boards to stop new hookups to sewage treatment plants that were not meeting standards. This provision has made pollution control a major priority for cities and sanitary districts in California. The ink was hardly dry on Porter-Cologne when the Federal Clean Water Act of 1972 passed, which basically required permits for all discharges to surface waters, and more treatment to remove pollutants. The federal government also offered to pay 75% of the cost of upgrades to municipal dischargers.

Thus, in the early 70s, we had in place strong state and federal laws for better pollution control, and an institutional framework to implement them. Did this system work? In fact it worked very well. There was nowhere in the country where upgrading of pollution control facilities was accomplished more rapidly than in the San Francisco Bay Area. Pollution loading to the Bay has declined by about 85% since the mid-60's, even though the population is much bigger.

While this dramatic improvement was taking place in pollution control, other changes were taking place in water diversions and water rights. In the 1970s, elements of the *California Water Plan*, approved by the voters in the 60s, began coming on line, in addition to earlier diversions for the large federal Central Valley Project. This process has since turned into one of the great environmental catastrophes in North American history. For striped bass, salmon, steelhead, and other migratory species, some critical threshold was clearly exceeded. In a single generation we have seen these species, once at world class abundance, becoming candidates for the Endangered Species List.

Thus we have this extraordinary juxtaposition between major improvements in pollution control on one hand, and a catastrophic decline in the fish that these multi-billion dollar pollution control efforts were supposed to protect. This disaster was entirely due to actions of government. All the dams and diversions were government projects, and all the decisions as to where that water would go were made by government agencies. This point is worth remembering when someone tells you that government is now unable to remedy these problems.

> “Millions of urban users drink substandard water while we apply pure snowmelt to alfalfa.”

Was this disaster necessary, a kind of price that must be paid for progress? And, can this damage be undone? To answer these questions it's necessary to briefly look at how we use water in California. Of the water we divert from rivers or pump from the ground, our so-called developed water supply, over 80% is used by irrigated agriculture, and less than 20% is used by cities. Our conflicts over water in California are not between north and south, since all the urban users together are not very important, but between aquatic habitat and agricultural use.

California's crops have a combined value of about $20 billion per year, the highest total in the nation. But this is only about 2% of California's trillion dollar economy. So irrigated agriculture in California uses over 80% of the State's developed water supply to grow crops that add about 2% to its economy.

How does California agriculture use water? The largest users of water are the lowest value crops. For example, irrigated pasture uses almost as much water as all cities in California put together. Four low value crops — irrigated pasture, alfalfa hay, cotton, and rice — use about 40% of California's water. Together these crops add only about one quarter of one percent to the state's overall economy. Moreover, all these low value crops are widely grown elsewhere. If we took some water away from these crops for people and fish, we would still have water for all our oranges, lemons, tomatoes, almonds, pistachios and grapes. The way we spend water in California suggests that we do not have a shortage, but rather, more water than we can wisely use. Our alleged shortages are really an artificial result of the way the State of California misallocates water.

This brings us around to California's water rights process as administered by the State Water Resources Control Board. The water rights function of the State Board has sometimes been seen as a counterpart to its water quality program. However, the two are very different. The problems of this inadequate system for regulating water allocations in California have three root causes. First, weak appointments. With a couple of exceptions, the appointments by our last two governors to the Water Resources Control Board have been of people who could be relied on to protect the status quo on water, despite an ongoing disaster with the fish. Second, weak water law, which gives the State Board the authority to better allocate water, but not the obligation. Third, a woefully underfunded Division of Water Rights, which has fewer staff for the whole state than the S.F. Bay Regional Water Quality Control Board has for pollution control alone. These low funding levels are not based on lack of money, but rather on a conscious decision by previous administrations to starve the regulators.

In summary, the State's system for managing water is wildly out of balance. We have undone, through a dysfunctional water rights process, most of the good promised by our multi-billion dollar investment in better water quality. Fish have not been the only victims of California's system of water allocation. Millions of urban users drink substandard water while we apply pure snowmelt to alfalfa.

Is this situation beyond retrieval? Meaningful restoration will not happen so long as existing allocations are taken as permanent and unchangeable. Giving the fish everything they need — except more water — won't work.

➤ MORE INFO?
lpk@rb2.swrcb.ca.gov

RESTORATION LESSONS

PERSPECTIVE

Strictly Speaking: The Restoration Concept

William R. Jordan III
University of Wisconsin

Creation, it has been said, begins with a word. So when we get involved in the work of creation — or re-creation, which is a very similar thing — it makes sense to be very careful about the words we use, since in a very real sense they will determine both the meaning of the work and the landscapes resulting from it.

Let's start by taking a close look at two of the words we use to label our work — "rehabilitation" and "restoration" — considering what we mean by them, and what we might expect to happen if we use them in our attempts to conjure with the ecosystems of San Francisco Bay.

One of the two, "rehabilitate," is a more general word. It's Latin root means "to clothe," and it means basically to fit out for use — like getting dressed when you get up in the morning. It is right to use this word as a kind of blanket term to cover all the things you might want to do on behalf of the Bay and its well-being. But it is also important to keep in mind that it is a general, inclusive, term. In fact, it is so general, that in practical terms it can mean almost anything that is intended to bring about a positive or desirable change. Thus it can refer to healing, for example, or stewardship or reclamation or preservation or simply making a place nice, whatever that might mean.

> "Restoration is the only management paradigm that is committed specifically to the perpetuation of the landscape on its own terms."

This being the case, it is important to realize that the term "rehabilitation" will never be enough to specify or prescribe or describe any actual conservation effort. For that we need terms that are far more specific.

Take restoration, for example. "Restoration" is perhaps the narrowest of the words in the "rehabilitation" family, and the most demanding. If "rehabilitation" means fitting or refitting something for use, restoration means making it be — or behave — the way it did at some time in the past, whether or not we happen to find that useful or nice or even healthy.

The difference is crucial for several reasons. First, with respect to the ecosystem, this is the only management paradigm that is committed specifically to the perpetuation of the landscape on its own terms, and for this reason it constitutes the best prospect for the survival of historic and classic ecosystems over the long term.

Second, and inseparable from that, it implies and enacts a distinctive kind of relationship with that landscape. This relationship is, I think, uniquely respectful of the landscape. In fact it is respectful to the point of being self-consciously noncreative, and so is an exercise in humility and self abnegation. Yet, unlike "preservation," it is manipulative, and therefore implicates the practitioner in both the destruction he or she aims to reverse, and also in the uncertainty — and ultimately the impossibility — of the restoration process itself. This is of profound importance because it brings us into contact with the most problematic aspects of our relationship with nature — aspects we will have to deal with if we hope to achieve the sort of communion with the rest of nature on which conservation will ultimately depend.

Third, it creates a positive, challenging, inspiring context for action.

"Rehabilitation" is so general, and so vague as to objectives that it doesn't mean a lot and certainly doesn't inspire a lot. Restoration, on the other hand, offers the promise of recovering something that is not only highly desirable but highly specific. This is important because it is a contribution to real bottom-up conservation — conservation that is supported by the people who live in the ecosystem — and a way out of dependence on financial life-support from the top, from agencies and foundations.

This is crucial because in the long run the health of an ecosystem is going to depend on the people who inhabit it. In the case of the San Francisco Bay Estuary, you have an ecosystem shaken to its foundations by profound changes in topography, hydrology and land use. How far we go in the new century toward bringing a balance between culture and nature to this ecosystem is going to depend not just on our scientific acumen but also on our ability to work with communities of human beings, the dominant species in the system.

For these reasons, the words "restoration," "rehabilitation" and "reclamation" all need to be used carefully. Restoration both creates landscapes and generates meanings that no other word creates. So it is a critical component of a comprehensive conservation effort. But it is important to keep in mind that it is only one of the many games we play with nature. The others are important too. And we gain full value from them only when we use them clearly, carefully discriminating them from each other (Jordan, SOE, 1999).

➤ MORE INFO?
newacademy@execpc.com

NATIVE FISH IN STREAMS

Robert Leidy, U.S. Environmental Protection Agency

Streams in the San Francisco Estuary provide an opportunity for the restoration of native fishes that is not available in the Delta or Suisun Marsh or in the Central Valley. About 75 small watersheds ring the San Francisco Estuary, with drainage areas ranging in size from tens of square kilometers to, in the case of Alameda Creek, over 1,800 square kilometers. Within these watersheds, average annual discharge ranges from a few cubic feet per second (cfs) to, in the case of Napa River, over 200 cfs.

Many of these streams support intact assemblages of native fishes. About 25 native stream fish species occur in these smaller Estuary streams, as compared to about 40 in Central Valley proper watersheds. Surveys conducted between 1993 and 1997 to determine where the best remaining streamfish assemblages occurred in the Estuary found that 75% of the 280 sites sampled were dominated by native fish in terms of species number. In addition, 84% of the sites sampled were dominated by native species in terms of abundance as measured by biomass.

Some of the watersheds dominated by native species cover a wide geographic area. The Alameda Creek drainage had several streams with entire reaches or links dominated by native species. About 70% of the Alameda Creek watershed, in terms of stream miles, is probably dominated by native fishes. Some other streams dominated by native fishes include Coyote Creek upstream from Coyote Lake, Saratoga Creek, the Guadalupe River, Stevens Creek and entire drainages in Marin, Sonoma and Napa Counties.

Native Fishes in Central Valley versus S.F. Estuary Watersheds

Watershed	Deer Creek	Mill Creek	Napa River	Sonoma Creek	Alameda Creek	Coyote Creek
Watershed Area (km2)	540	402	1080	396	1800	914
Mean Annual Discharge (cfs)	373	297	208	65	123	67
Number Extant Native Fish Species (with extinct species)	10	8	17	12	16 (17)	12 (20)

Source: Robert Leidy

One good example of native fish dominance is on the Napa River at the Napa River Ecological Preserve, where one sampling site supported nine native species — a number difficult to equal in any comparable Central Valley stream. Species observed at the Ecological Preserve site included Pacific lamprey, steelhead/resident rainbow trout, Sacramento sucker, California roach, Sacramento pikeminnow (a.k.a. squawfish), hardhead, prickly sculpin, riffle sculpin, threespine stickleback and tule perch. Moving up to the headwater areas the number of native species diminishes but natives still dominate. A similar pattern occurs in the Sonoma Creek drainage: about mid-elevation

NEW SCIENCE

Steelhead Habitat Limits in Sonoma Creek

Neither sediment or temperature conditions appear to be limiting steelhead populations in Sonoma Creek. To determine if these factors were influencing the quality of the available steelhead habitat, the Sonoma Valley Watershed Station (SVWS), a project of the non-profit Sonoma Ecology Center (SEC), performed a spawning gravel suitability assessment and a thermal monitoring program in Sonoma Creek and major tributaries in 1998. Sediment and temperature are among stressors identified by the S.F. Bay Regional Water Quality Control Board in designating Sonoma Creek and its tributaries as impaired.

Researchers selected potential spawning locations based on informal observations of adult spawners and juvenile steelhead, electro-fishing surveys, and field observations of suitable spawning habitat. Using a modified McNeil sampler, they collected twenty-four samples at eight sites. Individual samples at each site were combined into a random-stratified composite sample to characterize the range of sediment sizes present in potential spawning gravels. The samples were sorted into sixteen size classes and weighed to quantify the percentages of fine sediment present in the spawning gravels. Results were interpreted based on previous studies giving generalized standards for suitable spawning substrates: the percentage (by weight) finer than 0.85 mm should be under 14%, and the percentage finer than 3.35 mm should be under 30% (Kondolf 1988).

Researchers chose thermal monitoring sites based on their potential to provide juvenile steelhead rearing habitat, selecting twelve representative sites in upper mainstem Sonoma Creek and several main tributaries in well-shaded deep pools where relatively cooler water temperatures provide the best thermal refuge for juvenile steelhead. They monitored summer (low-flow) temperatures using HOBO, temp data loggers which measured and stored temperatures hourly or bi-hourly from June to October. Optimum and critical threshold requirements have been developed by the California Department of Fish and Game, EPA, and other agencies and researchers: optimum temperatures are 45-61° F (Flosi and Reynolds 1994) and the critical thermal maximum is 84.5° F (Lee and Rinne 1980).

The spawning gravel study results indicate that gravel quality is adequate for steelhead spawning. Preliminary analysis of the thermal monitoring results indicates that temperatures often exceeded the preferred range for juvenile steelhead for brief periods but did not reach the critical thermal maximum. Based on the evaluation of the results, fine sediment and temperature are not greatly influencing the quality of spawning or juvenile rearing habitats. Future research and restoration efforts should concentrate on other potential limiting factors (McKnight & Katzel, SOE Poster, 1999).

➤ MORE INFO?
sec-mcknight@vom.com

Criteria for Watershed Restoration Prioritization

- Relatively intact assemblages of native fishes and amphibians.
- Maximum range of natural variability of hydrologic regime (75%-125% of reference).
- Floodprone area unmodified by cultural processes.
- Spatial structure instream habitat approaching reference (75%-125% of reference).
- Landscape hydrologic connectivity intact.

eight species of native fishes occur, and only one exotic species — mosquito fish — was encountered. Moving up to the extreme headwaters only riffle sculpin and steelhead/rainbow trout were found.

How do such assemblages compare with conditions in Central Valley streams? According to Peter Moyle at U.C. Davis the two Central Valley streams that support the most native fishes are Deer Creek (10 native species) and Mill Creek (8 native species) in the northern Sacramento Valley. As an example, these numbers compare to the 12,16,and 16 native fishes still supported by Sonoma, Alameda and Napa River watersheds respectively (see chart p.19).

With the listing of several salmon species as endangered or threatened, interest in restoring these salmonids and the streams that support them is growing. San Francisco Estuary historically supported large runs of steelhead. Places like Sonoma Creek were world famous for their steelhead runs. Historical research suggests that Estuary streams once had at least 25 steelhead runs, most of them in the North Bay. Current runs persist in 19 of these drainages, though the number of fish in various runs ranges from only a few per year to 100-200 fish. Thus despite the absence of any focused restoration,steelhead runs still occur in many of our drainages.

Restoring or maintaining these native fishes requires attention to the physical processes important to maintaining their habitats in a stream. One of the most important processes is

Candidate High Priority Watersheds for Restoration

- Sonoma Creek, Sonoma County
- Petaluma River, Sonoma County
- Huichica Creek, Sonoma County
- Napa River, Napa County
- Miller Creek, Marin County
- Corte Madera Creek, Marin County
- Mt. Diablo Creek, Contra Costa County
- Alameda Creek, Alameda and Santa Clara Counties
- Coyote Creek, Santa Clara County
- Saratoga Creek, Santa Clara County
- Green Valley Creek, Solano County

PROJECT IN ACTION

Resurrecting Codornices Creek

Restoration projects both completed and in the works for Berkeley's Codornices Creek enhance over 3,000 feet of this urban stream. The creek traverses parks, backyards, industrial zones and a racetrack and suffers from urbanization in its watershed, which has led to excessive erosion and deposition. The straightened, narrow channel of lower Codornices has become prone to flooding due to runoff from the city's paved surfaces. Many of these problems are being addressed by joint efforts on the part of local agencies, creek groups, and citizens, and by several restoration projects.

The first 430-foot-long restoration project, in 1994, removed a stretch of creek from an underground culvert in Berkeley's flatlands. Along the restored creek bank a volunteer citizens' group planted a wildflower garden and meets regularly on weekends to keep the creek clean. In the fall of 1997, another restoration took place in a spot where consistent flooding was undermining local building foundations. Restoration included widening the straight, narrow stream channel and giving the banks a more gentle slope, creating a few meanders in the channel, and revegetating the banks with native riparian trees and plants. Since then, the new channel has contained even El Niño's stormwaters without flooding and hosted the odd steelhead trout.

A third restoration effort for a degraded stretch of stream associated with a local affordable housing project is being designed by the Waterways Restoration Institute. The restoration will remove the concrete channel, recreate the stream's meanders and install natural riparian vegetation.

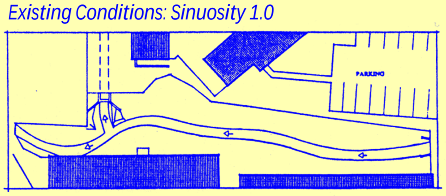
A fourth restoration now in the planning stages will transform summer soccer fields into winter flood plains just before the creek flows beneath I-80. The project will create a creekside trail connection to the Bay Trail, restore native willows and other riparian vegetation, and reduce flood problems. It also restores habitat for the steelhead that have been reappearing in the creek every winter (Adapted from Bradt, *Creek Currents*, 1999). See also Battle and Butte Creeks, p.24

Participants: Urban Creeks Council, Waterways Restoration Institute, cities of Berkeley and Albany, U.C. Berkeley, East Bay Conservation Corps, local citizens and businesses.

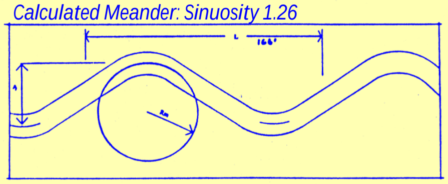
➤ MORE INFO?
wriberkeley@earthlink.net

Meander Design

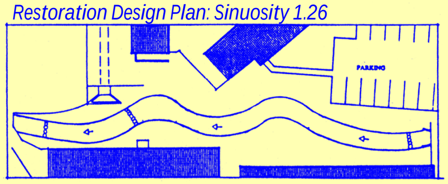
Existing Conditions: Sinuosity 1.0



Calculated Meander: Sinuosity 1.26



Restoration Design Plan: Sinuosity 1.26



Source: Waterways Restoration Institute

flooding in areas with intact flood plains, such as occurs for example in some reaches of Alameda and Sonoma Creeks, the Napa River, and many undammed smaller streams. Within the Central Valley, most watersheds contain large dams. Within the Estuary, however, especially in the North Bay, a number of watersheds remain free of major dams. This has important implications for restoration, not only from a hydrologic/hydraulic point of view, but also in determining the likelihood of successful invasions of non-native fish. Dams, and the reservoirs behind dams, are major sources of exotic species. One likely reason why native species predominate in many of our smaller streams is that these drainages typically do not contain large dams that significantly alter flow regimes. The relationship between the occurrence of native and non-native fishes in dammed versus undammed streams needs further study.

Several other geographic considerations make Estuary streams unique compared to other areas, among them near-surface salinity. Streams around the Estuary are temporally and spatially isolated from one another because they drain into a predominantly salt-water environment. Therefore freshwater fishes typically can only move between drainages during periods of high fresh water outflow from the Delta. As a result, Estuary streams appear to be "protected" from invasions by exotic species from downstream sources or non-native species pools. This situation is quite different in the Central Valley, where large, low-elevation fresh water river systems act as a continual source of exotic species to tributary streams.

Geography also plays a role in outmigration success for anadromous fishes. Native anadromous fishes such as steelhead must travel from their natal stream to the open ocean, where they feed and grow before returning to their natal stream to spawn. Outmigration distance plays a big role in determining juvenile and adult survival and ultimately the success of populations within streams. For example, outmigration distances for steelhead to the ocean from Estuary streams such as Napa County's Miller Creek, Sonoma County's Sonoma Creek, Alameda County's Alameda Creek and Santa Clara/San Mateo County's San Francisquito Creek, for example, are 2-5 times less than that faced by steelhead coming from Central Valley streams such as the American River, Deer Creek, or other upper Sacramento River tributaries. In addition, fish migrating out from Estuary streams do not have to contend with the myriad diversions and pumps within the Central Valley and Delta — a significant source of mortality for migrating fish. Considered together, the above factors create a compelling argument for working to preserve and enhance Estuary streams.

Minimum Number Estuary Watersheds Supporting Historical and Current Populations of Steelhead

Estuary Region	Number of Historical Runs Steelhead	Number of Current Runs Steelhead	Number of Watersheds Unaffected By Dams or Diversions
Northern Bay	14	12	18
Central Bay	3	2	3
Southern Bay	8	5	4
Totals	25	19	25

REHAB ADVICE

- Identify and document reference streams as a tool for assessing impacts, setting priorities, developing design templates and monitoring restoration success. Too many restoration projects, not to mention mitigation projects, are being done in the absence of a reference framework. A reference stream should be a group of stream reaches within the same hydrogeomorphic class that represents the variation that occurs within that class due to natural and human causes.
- Develop functional profiles of our watersheds. Functions may be thought of as processes necessary for self-maintenance of an ecosystem. Functions might include maintenance of various water quality parameters, short or long term ground water storage, the range of variability in flow regime or habitat support for native fish or amphibians, etc.
- Develop variables to scale, measure and score such functions. Variables might include topographic complexity, the abundance of native fishes or some index of similarity between native fish assemblages and historic conditions.
- Compile scores from functional assessments separately for watersheds and compare them to reference scores.
- Establish restoration priorities based on the regional reference framework (Leidy, SOE, 1999).

➤ MORE INFO? leidy.robert@epamail.epa.gov

RIPARIAN FORESTS

Wetlands Ecosystem Goals Project

Riparian forest restoration and creation has been underway in the Bay Area for many years, with limited success. Of all the wetland types, riparian forest may be the most difficult to restore because it must exist in proximity to a stream or on a flood plain. Success in restoring riparian habitats depends on imitating natural habitat. Projects that ignore natural processes or that attempt to establish vegetation at unsuitable sites are almost guaranteed to fail.

In rural parts of the Bay Area,streams are subject to rapidly changing conditions of erosion and sedimentation.

Most are eroding along their banks and cutting down below their historical flood plains. As a result, their riparian forests are being lost. Restoring them will require managing watersheds to reduce runoff and erosion.

Most of the region's urban streams have been channelized — severely limiting their potential for restoration. Flood control levees may support some riparian trees, but only to the extent that this does not compromise the integrity of levees or other structures.

Objectives for flood control and riparian restoration have been met successfully on the lower reaches of the Bay region's Coyote Creek and Wildcat Creek (Riley 1998) and Novato Creek (Prunuske Chatham 1998). Thus it is possible to design projects that provide flood control benefits and significant riparian functions. Many of the Bay Area's flood control districts are responsible for maintaining projects that were constructed decades ago, when there was much less appreciation for naturally functioning riparian systems. Today, together with dozens of citizen-based creek restoration groups, many are working to repair some the damage done by early projects and to restore Estuary creeks, watersheds and riparian vegetation.

According to the Wetland Ecosystem Goals Project, high quality riparian forest habitat extends in a continuous corridor along a stream course; extends laterally from the stream channel across an unimpeded flood plain; forms a natural transitional ecotone with the adjacent uplands;is free of domesticated animals, human disturbance and invasive plants;and supports a diversity of native understory and canopy plant species. Likewise, high quality willow groves, once abundant in the Central Valley and South Bay, have hydrological conditions (including water quality) suitable to ensure long-term support of grove vegetation;have a natural transitional ecotone with the adjacent uplands;and should be free of domesticated animals and human disturbance.

NEW SCIENCE

NeoTropical Migrant Habitat

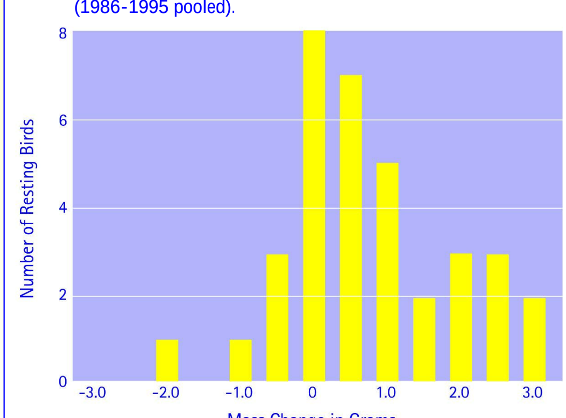
Many wildlife managers believe that small islands of habitat are less important than large, contiguous areas. But this way of thinking is usually based on the needs of breeding birds. In urban areas, even small islands of riparian habitat can be important for neotropical migrants. Riparian areas in urban settings, even if fragmented or newly-restored, may be important critical resting and refueling spots for neotropical migrants. A long-term banding study at the South Bay's Coyote Creek Riparian Station (now being conducted by the S.F. Bay Bird Observatory) revealed that almost half (49.3%) of the visiting migrant Pacific-slope flycatchers *(Empidonax difficilis)* gained mass at the site. Mean mass gain was 0.3 grams, not an insubstantial gain considering that the average weight of these birds is only 10.5 grams. Among the birds studied, 29.1% maintained mass, and only 21.5% lost mass. Resting birds gained an average of 0.3 grams of fat, increasing their potential flight range by about 50 kilometers.

Willow flycatchers *(Empidonax traillii)*, another neotropical migrant, with an average weight of 11.3 grams, gained an average of 0.7 grams, with a mean stopover of 6 days. Similar results were found for orange-crowned warblers, yellow warblers, Wilson's warblers, and Swainson's thrushes during both spring and fall migrations. Newly-restored riparian sites may be even more valuable to some neotropical migrants than mature areas, due to their new growth, which produces a foliage canopy that attracts more insects and birds. Pacific-slope flycatchers *(Empidonax oberholseri)* moved freely between a newly-restored (7-year-old) site and a mature riparian corridor; however, 90% of birds studied were found at the newly-restored site, indicating a preference for this habitat (Otahal, Unpublished Data, 1999).

➤ MORE INFO? neobird@aol.com

Mass Change Distribution

Mass change distribution for resting willow flycatchers (1986-1995 pooled).



REHAB ADVICE

Riparian Forest

- Incorporate setback levees in flood control planning to restore or maintain flood plain and riparian habitats.
- Allow natural stream processes to maintain channel form,provide flood flow passage, and maintain riparian vegetation.
- Control or remove non-native invasive species (giant reed, German ivy, eucalyptus, and Himalayan blackberry).
- Provide buffers at least 100 feet wide beyond the outer edge of the riparian vegetation.
- Minimize trails, grazing, and other disturbance within the riparian corridor.
- Utilize native plant species from the local area.
- Establish an appropriate hydrological regime to ensure long-term persistence of native species.

Willow Grove

- Utilize native willow and other plant species from the local area.
- Provide buffers of at least 100 feet in width beyond the edge of the grove.
- Establish an appropriate hydrological regime to ensure long-term persistence of native species (Goals Project, 1999).

➤ MORE INFO? www.sfei.org

PROJECT IN ACTION

Creek Keepers Plant Trees

Every year for the past four years a handful of students from Richmond High School in the East Bay have been collecting, growing and replanting native trees along the banks of Wildcat Creek. The Creek Keepers program, run by Friends of the Estuary, employs up to six students — providing them with environmental leadership opportunities and hands-on watershed restoration work.

In terms of their work on riparian forests, the students gather acorns of coast live oak, seeds of California buckeye, and cuttings of dogwood and willow, as well as baynuts, from the Alvarado area of Wildcat Canyon Regional Park. They then propagate the seeds and cuttings at the high school greenhouse, generating several hundred of each type of tree per year. The young trees are then transplanted into larger pots, moved up to a park maintenance yard, and later planted along creek banks by the students under the supervision of local park staff.

Planting sites must be carefully selected, as the largely south-facing bank is hot, dry and riddled with very poor serpentine soil (which contains potentially toxic metals such as magnesium, chromium and nickel). Another challenge to trees putting down roots is the highly unstable nature of the area, which lies along the Hayward fault and has been disturbed by previous large-scale restoration projects.

Though numerous new trees are lost to mudslides, storms and vandalism each year, many have survived and now offer a knee-high hint of riparian forest (Cochrane, SOE Poster, 1999).

➤ MORE INFO? sc@rb2.swrcb.ca.gov

DAMS & DIVERSIONS

Philip B. Williams, Philip Williams & Associates

The Central Valley's water engineering infrastructure, particularly the massive projects completed in the last 50 years, have transformed San Francisco Bay from a naturally functioning self sustaining ecosystem to the largest 'regulated' estuary in the world.

The huge ecological impacts of these major human interventions can only be fully appreciated if we understand two important concepts. First the environmental integrity or health of the watershed ecosystem is based on the integrity of the physical or geomorphic processes that create our wetland landscapes and sustain the biota that use them. Second, over time these landscapes have an inherent tendency for self restoration or 'healing', the same as what Hippocrates described as 'physis', the self-healing tendency of the human body.

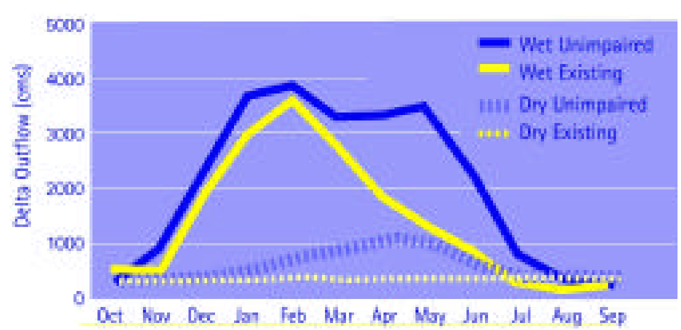
In terms of environmental integrity, every watershed has a unique geologic and climatic history that created its particular landform by the action of flowing water eroding and depositing sediments. Certain parts of the landscape, among them alluvial floodplains, river channels, and estuarine wetlands, persist over tens of thousands of years in an evolving dynamic equilibrium responding to periodic floods, tectonic events and sea level rise. Thus a watershed is a product of its own evolution and like a human being, contains a sort of virtual DNA that determines the character of the particular river that drains it. Over time a particular biota evolves to take advantage of these physical processes and landforms. In this way, the integrity of the whole ecosystem is dependent on the physical processes that sustain it. The interaction between flow, form, flora and fauna is what we mean by the term "living river."

The construction of dams and diversions in the Central Valley not only represented a massive injury to the ecosystem's health; but their persistence and operation is sustaining chronic illness because of their deleterious effects on key physical processes — and their prevention of self healing in the landscape. Like medical doctors, we should be looking at causes, not symptoms, of our patient — the Estuary's — poor health. The Estuary clearly shows five pathological conditions:

Estuary Pathologies

- Arterial Infarction, blocking of pathways in the system. For example the physical presence of large dams has interrupted the migration of anadromous fish on 90% of the watershed's rivers.
- Arteriosclerosis, or narrowing and hardening of the arteries. The operation of flood control dams has allowed the encroachment on floodplains and hardening of riprapped river banks.
- Hemophilia. Diversions for consumptive use reduce average flows to the Estuary by about 50% and seasonal flows in dry years by about 85%.
- Atrial fibrillation. Flood control reservoir operation has practically eliminated the natural heartbeat of the river — the pulse of smaller floods — thereby eliminating natural floodplain functions.

Wet & Dry Year Flow Comparison



PROJECT IN ACTION

Dam Removal on Butte and Battle Creeks

Demolition of five P.G. & E. dams on Battle's two forks and tributaries is slated to begin in 2000. The demo project, along with the retrofit of three other dams with fish screens, is the product of a much-touted agreement between conservation groups, CalFed, P.G. & E. and private landowners. The result will not only be restoration of 42 miles of salmon spawning grounds, but more importantly more water for fish. Minimum required flows of 3 cubic feet per second will be increased up to around 40-50 cfs (pre-dam base flows were around 120 cfs).

Elsewhere in the watershed, five dams have already come down in the middle reaches of Butte Creek, most owned by rice farmers. Now stakeholders in the lower watershed are completing studies on removing 8-10 fairly large dams and looking for funding to build 40-50 new fish screens.

In 1998, biologists counted a record 20,000 spring-run returning to Butte Creek to spawn (the historical high was 9,000). While biologists are hesitant to directly attribute the good numbers to dam deconstruction, especially since 1998 was a wet year, the creek's freer flows can only be helping. Butte's been getting better flows for fish on and off since the early 1990s as part of dam relicensing agreements, and the recent swell in salmon may be in part attributable to those increases (*Estuary*, December 1999).

- Anemia. Reservoir sedimentation and the reduction in flood flows has significantly reduced the movement of bedload in the lowland rivers. This transport of sediment is essential for sustaining the riverine morphology essential to fish and wildlife.

The massive plumbing system in place in the Central Valley was planned at a time when the idea of restoring a watershed ecosystem would have been considered absurd or irrelevant. The challenge now is to fully integrate management of the ecosystem with water resources management. In some cases this can be done by removing human interventions to allow living rivers to restore themselves. In others it means placing rivers on permanent life support systems — river management regimes that mimic natural processes. To carry these out requires redesigning and reallocating river flows in a rigorous accountable way. Most important it requires us to articulate a comprehensive vision of how the entire water management system can be redesigned and reoperated to accomplish contemporary river and estuary management objectives.

REHAB ADVICE

- Restore processes, rather than landscapes (don't preserve floodplain, for example, without providing water for floods).
- Recognize that our water project infrastructure is obsolete — it's time to free ourselves of the legacy of political decisions made 60 years ago about how to manage California's water and to re-evaluate this infrastructure in terms of today's societal values and goals.
- Progressively remove major interventions such as dams, to allow rivers and wetlands to restore themselves. Conduct audits to determine whether and which dams and diversions are still meeting societal goals and change the operation of, or decommission, those that don't. (One way to do this would be to extend the current Federal Energy Regulatory Commission relicensing process to all dams in California.)
- Place dammed rivers on permanent life-support. Develop new reservoir operation and river management regimes that mimic natural hydrologic processes. Develop a transparent and rigorous accounting system for water management.
- Articulate a clear, comprehensive, scientifically defensible vision for integrated river management throughout California (Williams, SOE, 1999).

➤ MORE INFO? http://www.pwa-ltd.com

NEW SCIENCE

Dam Removal Guidelines

Research to develop science-based guidelines for determining the relative merits of dam removal suggests that, contrary to popular perception, many dams could be removed with few harmful effects. Since 1998, a team of fisheries biologists, hydrologists, geomorphologists and economists have been examining selected dams in Northern California to create a checklist and analytical protocols. Such protocols can assist with technical and community- based evaluation of dam removal, modification or reoperation for the purposes of watershed improvement and stream restoration. Key points to evaluate are: net habitat benefits to fishes and riparian organisms; economic justification of continued dam operation; original beneficial uses of the dam, e.g. water supply, irrigation, flood control, navigation or recreation; hydrology and upstream and downstream geomorphological changes likely from removal; costs of decommissioning, e.g. sediment removal, construction traffic, monitoring; and social and political issues, e.g. nostalgia for the dam, archeologically significant structures, etc.

To test their proposed guidelines, researchers are conducting an environmental and economic analysis of removal impacts for two dams in Marin County's Tomales Bay watershed (Soulajule Dam on Walker Creek and Seeger Dam on Lagunitas Creek). In the case of Seeger, preliminary results indicate that the prior removal of a small agricultural dam increased fish habitat and improved the environment. Seeger Dam blocks migratory fish from some potentially good habitat in the same watershed. Analysis showed, however, that Seeger is so important to Marin County's water supply that it is not a viable candidate for removal. In the case of Soulajule, the dam's far upstream position precludes the creation of much new habitat as a result of removal. Indeed, preliminary results suggest that removal might actually lead to loss of habitat due to the creek drying up seasonally without the upstream storage and flow controls. These two examples (Walker Creek/Soulajule and Lagunitas/Seeger) illustrate the variety of issues that must be considered.

Researchers also organized several gatherings of dam removal experts from across the country. Experience from both the local dam research and activities around the country suggests that obstacles to dam removal are less difficult and expensive to overcome than many people think, and that in most cases removal is ecologically beneficial and worthwhile. A key factor remains the need to let natural processes take their course, rather than over-designing removal and restoration activities. Researchers plan to complete a set of objective, science-based guidelines for evaluating the pros and cons of dam removal by summer 2000 (McGowan et al., SOE Poster, 1999).

➤ MORE INFO? mcgowan@sfsu.edu

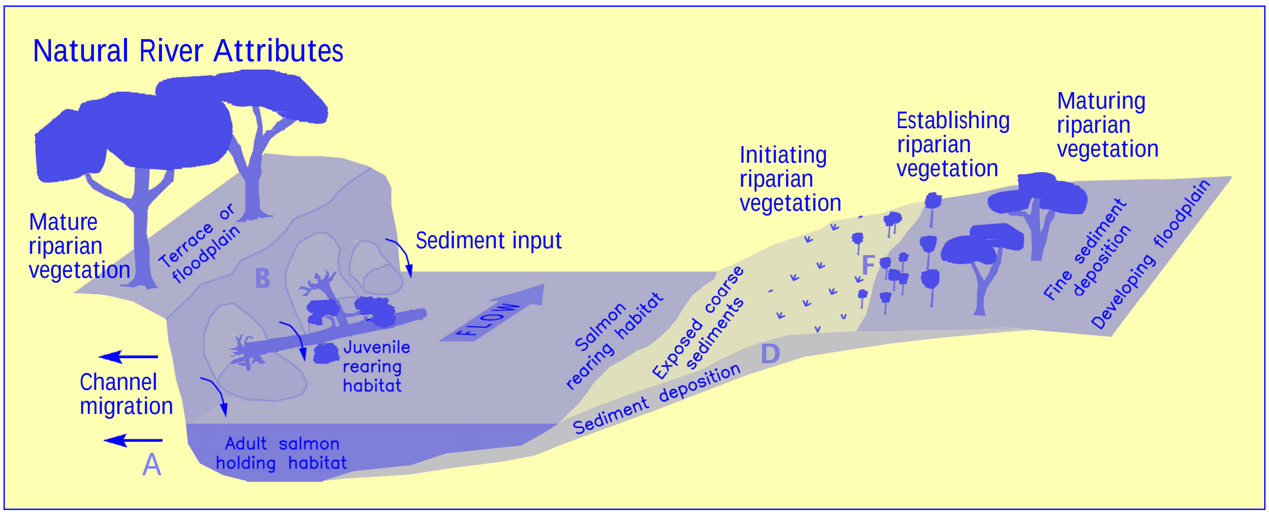
ALLUVIAL RIVERS

Scott McBain and Dr. William Trush
McBain and Trush

Many historical restoration and rehabilitation efforts in tributaries of the San Francisco Estuary have taken a structural approach, usually targeting a single species (e.g., fall run Chinook salmon). This has resulted in patchwork efforts that are eventually damaged or destroyed by high flow events, are usually short-lived, and do not benefit other ecosystem constituents. In this age where ecosystem restoration is becoming a driving goal, we are challenged with how does one rehabilitate an ecosystem, let alone restore it? Can a restoration strategy be quantified? We attempt to address this problem by developing attributes of a healthy alluvial ecosystem to guide rehabilitation efforts. The following attributes are important to the integrity of low-gradient, gravel-bed rivers of the Central Valley:

Healthy River Attributes

- Channel morphology is spatially complex and diverse (exposed gravel bars alternating with deep pools and geomorphically-linked floodplains). A dynamic alternate bar morphology is the foundation of a healthy river, as it provides a myriad of habitats at a wide range of flows.
- Streamflows are predictably variable and include the baseflows, winter storm events, snowmelt peaks and snowmelt recession that



A) A river with adequate space to migrate erodes the channel bank on the outside of the meander bend during high flows and B) encourages trees to topple. C) A deep pool forms here and creates good fish habitat. D) High flows scour and redeposit coarse sediments, forming a bar and providing clean spawning gravels. E) Ideal slow-water rearing conditions for juvenile salmon. F) Higher up the gravel bar surface a dynamic interplay occurs between changing seasonal water levels, channel migration and the growth of riparian trees.

PROJECT IN ACTION

Channel Reconstruction on the Tuolumne

In winter 2000 work will begin on a restoration project near the town of Hughson that will reconstruct a part of the Tuolumne River's natural channel destroyed by gravel mining, and thus help restore chinook salmon. The Tuolumne is the largest tributary to the San Joaquin River, and drains a 1,900-square mile watershed. Agriculture, ranching, mining and tourism dominate the region, and depend on the river for their sustained livelihoods. A group called the Tuolumne River Technical Advisory Committee completed a habitat restoration plan for the lower stretches of the river, partly in fulfillment of relicensing requirements for its dams and water development projects under a 1995 FERC settlement (Federal Energy Regulatory Commission).

Part of this plan are two "special run pond" projects designed to mediate some of the negative impacts of gravel mining on the river and its fish. Gravel mining on the Tuolumne began in the 1930s, when miners extracted valuable sand and gravel aggregate directly from the main channel, creating large pits up to 36 feet deep.

Excavating these ponds eliminated salmon spawning and rearing habitat, as well as entire floodplains and riparian vegetation. These large pits now trap all coarse sediment (gravel and cobbles) carried downstream by high flows, and provide warm-water habitat for native bass species that eat chinook salmon smolts as they migrate out to sea. Studies found dense populations of these predatory largemouth bass in the river — as many as 750 adult bass per river mile. Since every chinook salmon juvenile produced in the Tuolumne River must swim through this reach on their way to the ocean, bass have the potential to consume many thousands of juvenile salmon during the outmigration season. Reducing bass predation by eliminating their habitat is thus a high priority objective for restoring the chinook salmon.

Restoration planners considered a variety of alternatives for restoring one of the pools, known as "Special Run Pool 9," such as constructing a dike to separate the channel from the large backwater pit, or actively removing unwanted predator fish, leaving the pool intact. In the end, the best solution was to refill the entire pit with gravel and cobble to reconstruct a natural river channel, restore a natural channel and floodplain form, and revegetate floodplains with cottonwoods, valley oaks and other native vegetation. This approach will help restore natural river processes, provide additional riparian habitat, and improve conditions for chinook salmon by creating new juvenile habitat and eliminating predator habitat. By trying to restore ecosystem create and maintain a dynamic alternate bar morphology.

- Riffles and bars are frequently mobilized by moderate floods (one to two year flood).
- Point bars are infrequently scoured and redeposited by large floods (greater than five year flood).
- Sediment is transported through the channel at approximately the same rate as delivered by the watershed, and coarse sediment can route downstream from bar to bar (balanced sediment budget).
- Channel periodically migrates or avulses. This movement rejuvenates the channel, forms bars and floodplains, and encourages natural riparian regeneration (whereas dams, development, and even restoration projects, try to eliminate movement).
- Channel has a functional floodplain (inundated every 1-2 years;provides water storage during high flows;encourages fine sediment deposition and thus seedbeds for riparian regeneration).
- Extremely large floods "reset" channel location and scour mature riparian vegetation.
- Riparian plant communities are spatially and structurally diverse.
- Groundwater table in floodway fluctuates with streamflows.

The utility of these quantifiable "alluvial river attributes" is their simplicity: they underpin the riverine ecosystem. The native flora and fauna, which are often driving restoration efforts, evolved to these attributes and are best served by restoring these attributes. Furthermore, by targeting these natural attributes, most or all native species will benefit rather than a single species. Finally, these attributes can be improved even under most contemporary management constraints. Examples include pilot restoration efforts along the Trinity River and the habitat restoration plan for the Tuolumne River (March 1999).

REHAB ADVICE

- Acknowledge and encourage the dynamic nature of rivers, and how native plants and animals evolved through these dynamic qualities. Let dynamics be a success (objective) rather than a failure (avoidance).
- Create more variable stream flow regimes.
- Improve natural riparian vegetation.
- Maintain coarse sediment supply and significantly increase coarse sediment storage.
- Reduce fine sediment supply and storage.
- Establish riparian floodways and corridors for channel migration and adjustment that is continuous all the way from dams to the Estuary.
- Balance ecosystem needs with societal needs (McBain,SOE, 1999).

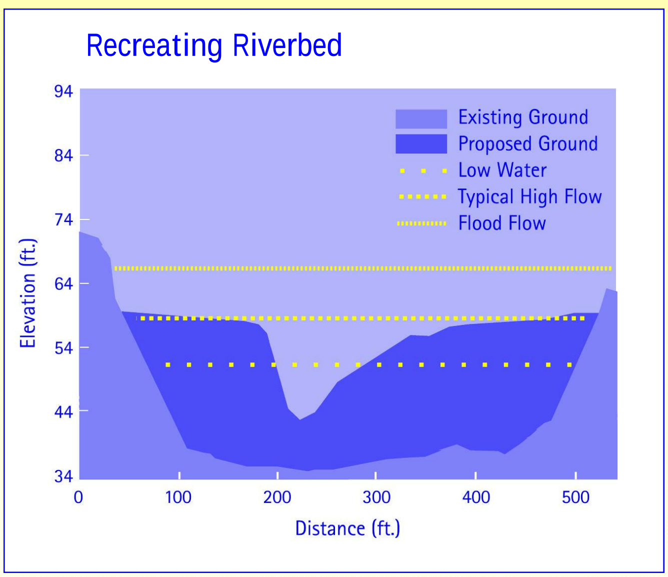
➤ MORE INFO? mcbtrsh@northcoast.com

processes, in addition to improving conditions for a single species, the project will be a large-scale experiment and monitored accordingly. When complete, the restored project reach may provide a permanent solution to decades-old problems, and represent a significant piece of the 52-mile Tuolumne River corridor restoration effort.

Participants: (Special Run Pool 9 Project) Tuolumne River Technical Advisory Committee and Turlock Irrigation District.

Consultants: McBain & Trush, Arcata

➤ MORE INFO?
mcbtrsh@northcoast.com or
tjford@tid.org



As shown in a typical cross-section through the special run pools, the existing channel is four times wider and at least two times deeper than it should be. Narrowing the channel will eliminate bass habitat, allow gravels to move through the reach, and provide floodplains for replanting riparian vegetation.

FLOODS & FLOODPLAINS

Jeffrey Mount
University of California, Davis

The floods and floodplains of the Sacramento-San Joaquin watershed perform hydrologic and ecological functions that support the well-being of the Bay-Delta estuary and its watershed. The problem is, although we're unanimous in the opinion that these functions are important, we're still not quite sure exactly how important they are. After decades of research emphasis on channel and riparian ecosystems, a rapidly growing body of scientific evidence is emerging that indicates we have underestimated the role of floodplains in ecosystem health and in water quality and supply.

The impact of floodplain land use change and water management on the Bay-Delta can be conceptually linked to alteration in "residence time,"or the length of time water, sediments, nutrients or other constituents spend within a watershed. With some exceptions, current land use practices, both above the dams and below the dams, act to reduce these residence times, leading directly to a decline in water quality and ecosystem health.

Flood and floodplain management typically move water through the system faster — attenuating hydrologic residence time. The extensive network of levees within the Central Valley separate rivers from their historic floodplains, restricting floodplain storage of high flows and reducing residence time by increasing regional flood stages (it used to take weeks for water to move through the San Joaquin River system,now it takes days). Dams act as sinks of water and sediment, and dramatically increase residence time where it doesn't do any biological good — behind the dam. Although dams may increase residence time during some floods, their use for water supply leads to a decrease in residence time on annual or decadal scales. Overdraft of groundwater basins, coupled with a reduction of floodplain recharge, exacerbates this decline in overall residence time of water in the basin.

Dramatic alteration in sediment residence time is commonly associated with flood and floodplain management. Levees, coupled with

PROJECT IN ACTION

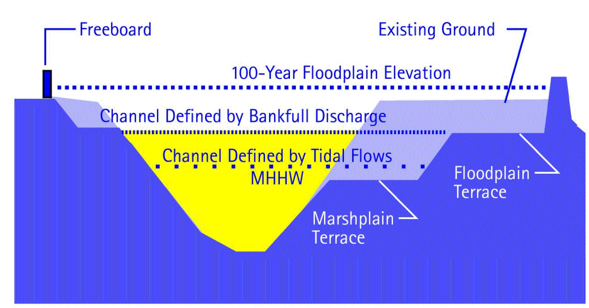
Napa River Floodplain Restoration

A coalition to develop a community-based, environmentally-friendly flood damage reduction plan for the Napa River through the City of Napa has produced a plan for a "living river" that is considered a national model for flood protection and river restoration. The Napa River drains 426 square miles of the California Coast Ranges. Historic repetitive flooding has occurred in the famous wine-producing watershed, with particularly damaging recent floods in 1986, 1995 and 1997. To address this flooding, the Napa Community Coalition formed to work with the Army Corps of Engineers on a plan to be completed in 2000.

The resulting plan moves away from previous flood-channel design standard methodologies (i.e. straight trapezoidal channels with floodwalls) and uses geomorphic principles to design a channel with long-term stability, increased water and sediment conveyance, and environmental benefits. Key design elements include: 1) a multi-stage channel providing the needed conveyance for 100-year flood protection for Napa city while restoring historic tidal marshplains and alluvial floodplains (see chart); and 2) a raised-bed bypass channel through a heavily developed area of the city. The bypass channel cuts off an existing meander bend; however, the bypass only floods during high flows (greater than dominant discharge), thus maintaining the oxbow meander during low flows, and avoiding typical problems encountered by wet bypasses, such as upstream erosion and silting of the oxbow.

Planners also conducted a complex sediment transport model study for the reach of river targeted for restoration. The model simulated various flow paths and suspended sediment movements and concentrations. Model results confirmed the general geomorphic stability of the channel design (including the removal of a planned grade-control structure upstream of the dry-bypass), provided estimates of expected sediment deposition on marshplains and floodplains, and showed associated decreased in-channel suspended sediment concentrations. In addition, planners developed a conceptual plan for enhancing over 1,000 acres of tidal wetlands, freshwater wetlands, alluvial floodplains and upland areas in the diked floodplain downstream of the City of Napa. The project will break ground in August 2000 and be under construction for the next 5-6 years (Wright & Williams, SOE Poster, 1999).

Geomorphic Channel Design



Participants: California Coastal Conservancy, California Dept. of Fish & Game, Napa County Flood Control District, National Marine Fisheries Service, S.F. Bay Regional Water Quality Control Board, State Lands Commission, U.S. Army Corps of Engineers, U.S. Environmental Protection Agency & U.S. Fish & Wildlife Service.

Design Consultants:
Philip Williams & Associates

➤ MORE INFO? hsiegel@co.napa.ca.us

reduced hydrologic variability, eliminate sediment storage and erosion on floodplains. In addition, levees that constrain channel dynamics act to inhibit sediment storage within and adjacent to channels. The result is that the average age of sediment on the floodplain becomes older, while the age of sediment in the channels becomes progressively younger.

The residence time of nutrients in the system has also been reduced. Management practices and levees prevent nutrients, via water and sediments, from reaching the floodplains where they help drive primary production in the food web. Land use changes and farming practices attenuate nutrient residence time and overall nutrient loading. This is exacerbated by shortened hydrologic and sediment residence times associated with floodplain management methods.

The decline in ecosystem health and water quality in the Bay-Delta Estuary is arguably driven by historical and present-day shortening of key residence times within the Sacramento/San Joaquin watershed.

REHAB ADVICE

- Enhance residence times of water in the basin through flood and floodplain management changes and ecosystem restoration.

➤ MORE INFO?
mount@geology.ucdavis.edu

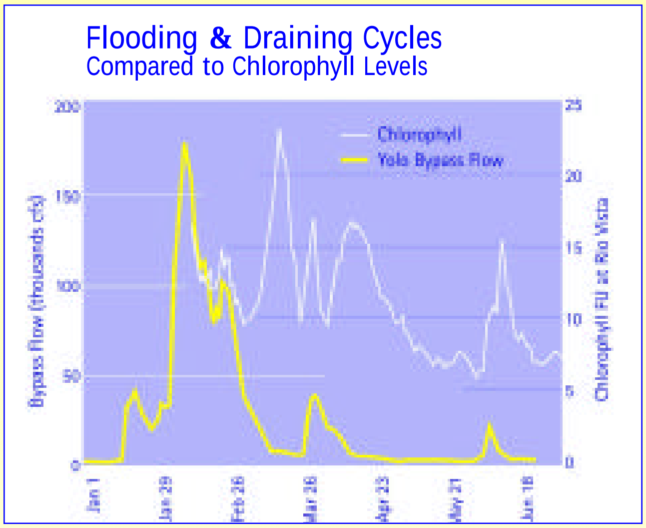
NEW SCIENCE

Yolo Bypass: Fish & Floodplains

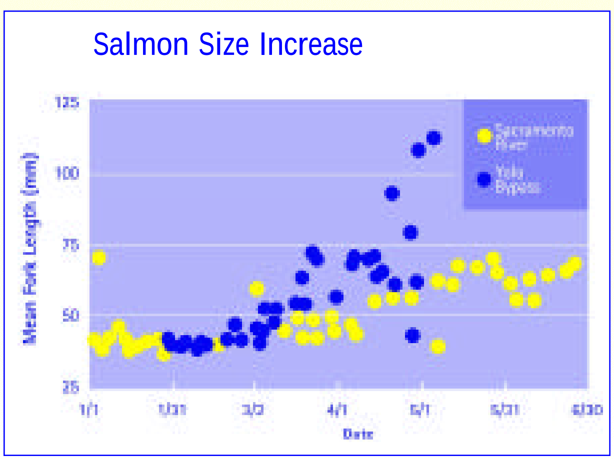
Research into fish use of the Yolo Bypass suggests that restoring floodplains, and providing for their seasonal inundation, are important tools for enhancing native fish species. The Yolo Bypass is a leveed, 59,000-acre floodplain engineered to carry flood flows from the Sacramento, Feather and American Rivers, as well as from the Sutter Bypass and westside streams and drains. The system seasonally floods approximately two out of three years, when it can double the wetted area of the Delta. During peak flood events up to 80% of the inflow from the Sacramento basin passes through the bypass. Recent studies indicate that such inundations, and the habitat and food they produce, are more important to the ecology of the Sacramento-San Joaquin estuary than previously thought. Floodplain inundations, a unique characteristic of wet years, may also be one reason high flow years enhance many Delta species. Research also suggests that seasonal inundation may actually give some native fish an advantage over exotic competitors, because it occurs during cooler winter conditions when natives are better adapted to spawning.

Fish sampling between February and May of 1997 and 1998 indicates that the bypass seasonally supports at least 40 species of fish (including native Delta smelt, splittail, steelhead trout, sturgeon, and winter-run Chinook salmon) and provides spawning and rearing habitat for several native minnows. Other findings suggest that the size of downstream-migrating young salmon increases faster in the bypass floodplain than in the Sacramento River, and that the growth of young salmon is enhanced by the higher water temperatures and feeding success in the bypass. Tracking of two groups of 50,000 tagged juvenile salmon simultaneously released in Yolo Bypass and the Sacramento River and then recaptured downstream demonstrated a higher survival index for the bypass (0.16) than for the river (0.09). In addition, analysis of water samples and salmon stomach contents show that the bypass is a primary pathway for organic carbon in the Estuary, including phytoplankton generated during the draining and filling cycles of the floodplain, as well as detritus. With such benefits to fish and support for the estuarine food chain, floodplain restoration and inundations should be considered a major tool for protection and enhancement of listed and native species (Sommer et al, SOE Poster, 1999).

➤ MORE INFO?
tsommer@water.ca.gov



Chlorophyll peaks downstream at Rio Vista were closely linked with flooding and draining cycles of the bypass.



The size of downstream-migrating young salmon increases faster in the bypass floodplain than in the Sacramento River.

PERSPECTIVE

Engineering VS. Mother Nature

Jeffrey Haltiner,
Philip Williams & Associates

The practice of environmental restoration has grown dramatically in recent years. While the precise meaning of the term "restoration" remains controversial, the recognition of the need to improve the physical, chemical, and biotic conditions in the Bay and watersheds is now widely accepted. However, the specific approaches used to restore or enhance the various ecosystems have varied widely, as have the results. There is a wide divergence of viewpoints on the benefits or success of restoration projects, ranging from the perspective that "restoration doesn't work" (Race 1986 and 1996) to the opposite view embodied by the "mitigation" approach that wetlands lost to development can be recreated elsewhere.

Within the broader discussion of "success", there is also debate over methods. Restoration can vary from a relatively simple approach (remove the prior interventions/alterations, and allow the site to restore naturally) to highly complex and structural solutions (which will require ongoing maintenance/management in perpetuity). While it may be instructive to argue between these extremes on a philosophical basis, the actual selection of a preferred restoration approach will likely continue to require consideration on a site-by-site basis. The complexity of factors which determine the preferred approach include such issues as: regional and local restoration goals, required multi-objective land use conditions/constraints affecting the site, cost considerations, and the net result of the physical processes which will determine the site evolution.

Where possible, the preferred approach to restoration is to remove or ameliorate the effects of interventions and allow natural processes to recreate desirable habitat. Where more structural or "engineered" approaches are necessary, these should be implemented in harmony with the forces that shape the particular ecosystem, encouraging the site to evolve to a more naturally functioning site. The approach is to develop a resilient system, adapted to the range of extreme influences, that achieves the restoration goals with the minimum required external influence. In selecting an "active" restoration approach versus a "let mother nature heal the site" approach, we can envision varying levels of activity:

Level 1: Do nothing; allow natural erosion and sedimentation processes to gradually restore geomorphic shape and function, assuming biotic processes will follow.

Level 2: Undo prior interventions (for example, remove a river levee to permit site inundation during large floods) and prevent future alterations. (Usually, this involves focusing on the primary interventions and major ecological forcing functions (site geomorphology, hydrology, hydraulics etc).

Level 3: Minimal site intervention to promote more rapid restoration (for example, restore the site morphology, revegetation etc.).

Level 4: Active restoration, including major regrading, recreation of features, removal of exotic species, creation of some habitat structures, etc. Perhaps a major focus on off-site issues as well, including restoring altered hydrology, sediment transport, water quality issues, etc.

"The approach should be to develop a resilient system, adapted to the range of extreme influences, that achieves the restoration goals with the minimum required external influence."

The factors that will prompt a more active or intrusive level of intervention include the following:

- The system is still "devolving" (ie, a stream channel is actively incising, and will do so for the foreseeable future).
- Desire to accelerate the timeframe of recovery.
- Multiple (and perhaps partially contradictory) site objectives.
- Inability to sufficiently alter the prior interventions (for example, watershed hydrology or sediment regime have been so changed that passive restoration processes will not achieve the project goals.)
- Undesirable site evolution without intervention (for example, in evaluating the potential for restoration of subsided, freshwater tidal wetlands in the Delta, it was determined that natural sedimentation processes would be inadequate to create the target site morphology, and the site would evolve towards something different, and less desirable.)
- Unacceptable consequences or risks to infrastructure on or near the site resulting from the uncertainty of non-managed restoration.
- Desire for priority species habitat (ie, endangered or threatened wildlife or vegetation) may provide an ecological basis for the site design/construction which differs from the historical site conditions.

All of the above considerations must be weighed on each site and project to select the preferred approach. In most cases, it will be an iterative decision process which balances what habitat the site is capable of supporting with what critical needs are according to local and regional goals.

Rather than discuss these options from a philosophical basis, we recommend development of clear project goals and schedules, coupled with an understanding of the possible future scenarios. To remain consistent with our desire to achieve project goals with the minimum amount of intervention, structural change and long-term maintenance, we need to evaluate the amount of initial intervention conducted using a long-term perspective. It is essential to establish the long-term trajectory of the site evolution from it's altered state to one providing the preferred functions. Key site monitoring criteria should insure that this trajectory is occurring approximately as planned, rather than focusing on the exact site conditions (for example, percentage of vegetation etc.) at any given moment (Haltiner, SOE, 1999).

➤ MORE INFO? haltiner@pwa-ltd.com

DELTA ISLANDS

Curt Schmutte
Department of Water Resources

To understand the complexity of habitat restoration in the San Joaquin-Sacramento River Delta,one must first be knowledgeable of the Delta's history. The Delta is a highly-altered ecosystem. Very few features resemble the landscape that existed just 150 years ago. Dredging, boating, levees, water management, development, introduced species, and farming have had an immense impact on the Delta's physical appearance and its biological systems.

Prior to 1850,the Sacramento-San Joaquin Delta was a tidal wetland. The Delta was drained for agriculture in the late 1800s and early 1900s. The Delta's peat soils formed during the past 7,000 to 11,000 years from decaying plants at the confluence of the Sacramento and San Joaquin Rivers. The drained peat soils on over 60 islands and tracts are highly valued for their agricultural productivity. Since they were initially drained, these soils have continuously subsided at rates ranging from 0.5 to 4.5 inches per year (subsidence is defined here as the decrease of land surface elevation on the areas of the islands and tracts on the land side of levees). The island surface elevations where peat was once present or is present today range from 5 to over 25 feet below sea level.

Given this altered environment, the Delta presents unique and challenging opportunities for much needed habitat restoration. The opportunities include setting existing levees back away from rivers, protecting remnant channel islands, building new channel islands, restoring flooded islands, restoring the peripheral Delta islands, establishing habitat on levees, and restoring deeply subsided interior Delta islands.

Reversal of the effects of subsidence in a corridor through the Delta is necessary to achieve ecological connectivity. The current lack of connectivity between Suisun Marsh west of the Delta and riparian riverine habitat east of the Delta limits the restoration of important migratory fish species.

NEW SCIENCE

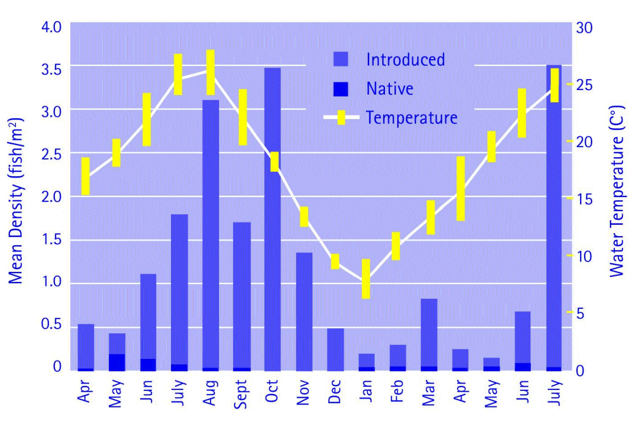
Delta Tidal Perennial Wetlands: Benefits to Native Fish?

Research suggests that native fish may not substantially benefit from breached levee restoration in the Delta. Current strategies for restoring native fish populations in tidal perennial wetlands of the Sacramento-San Joaquin Delta involve breaching levees around agricultural islands in order to restore perennial shallow water habitat. Some think restoration of shallow water habitat will promote primary productivity and increase spawning, rearing, and refuge habitat for native fish.

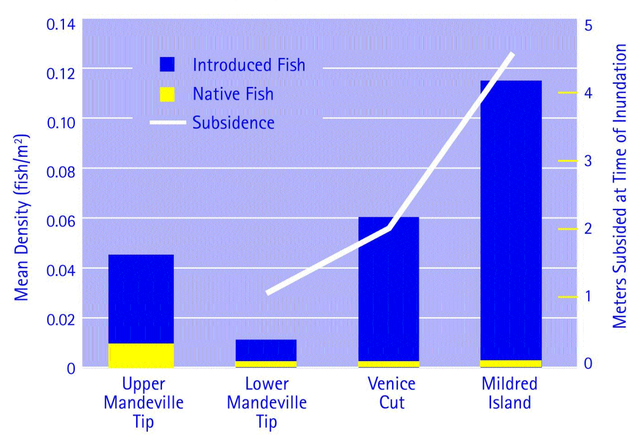
Recent studies have examined this issue by investigating fish assemblages, habitat associations and abundance among various habitats of previously breached agricultural flooded islands (ranging from 16 to 66 years since inundation) and a nearby reference site (continuously inundated by tidal action). Introduced fish were found to be the dominant inhabitants both monthly and seasonally at all sites. Nonetheless, the study suggests that physical attributes, most significantly temperature and submerged vegetation (type and density), are important factors in determining fish abundance and distribution within the flooded islands. Native fish spawned and reared during a narrow window in the early spring months under a cool temperature regime, ranging between 10 and 18°C. In contrast, introduced fish spawned and reared from late spring into early fall under a warm temperature regime, ranging between 15 and 25°C. Researchers also found significantly higher densities of resident native and introduced fish associated with submerged aquatic vegetation and significantly higher densities of native and introduced migratory fish associated with open, unvegetated habitats.

Research also shows that introduced fish prey on native fish. Due to the dominance of introduced species in tidal perennial flooded islands, a relatively narrow spawning and rearing window for native fish, and the potential for predatory impacts on native fish, this study suggests native fish may not substantially benefit from breached levee restoration activities planned in the Delta (Grimaldo et al., SOE Poster, 1999).

Fish Density by Month & Temperature



Fish Density by Site



➤ MORE INFO? lgrimald@water.ca.gov

Steve Johnson of The Nature Conservancy in 1997 said:"From an ecological perspective, there needs to be tidal freshwater wetlands covering the full range of ecosystem gradients in the Delta, not just a few points here and there with the rest of the tidal wetlands hugging the shores of the eastern Delta. To achieve this range, we simply must find a way to restore elevations on western islands and ultimately get some of them back into tidal circulation."

Reversal of the effects of the subsidence is also critical for the restoration of natural hydrologic processes in the Delta. The predevelopment Delta was a flood plain for the Sacramento, Mokelumne and San Joaquin rivers. The relatively long predevelopment residence time for water in the Delta promoted efficient nutrient cycling which supported a diverse and rich ecosystem. Ecological restoration in the Delta must include a long-range plan for reversal of the effects of over 100 years of subsidence to bring some island surfaces in the western and central Delta back to sea level and restore hydrologic processes and ecological connectivity across the Delta. Any long-term approach must consider a combination of techniques for reversing the effects of subsidence and integrating these efforts with ecosystem restoration.

The primary cause of subsidence is carbon loss due to microbial oxidation of the peat. The peat soils contain a complex mass of carbon that microbes such as bacteria and fungi use as an energy source, converting the carbon to carbon dioxide gas. Under agricultural conditions, more carbon is lost through this decomposition of the peat than is gained by crop residues, resulting in loss of land surface elevation. Under predevelopment tidal wetland conditions, more carbon accumulated under the water-saturated conditions than was lost through microbial decomposition of wetland plant residues. This resulted in the formation of the peat. Similarly, the results of preliminary research conducted by the U.S. Geological Survey in cooperation with the Department of Water Resources on Twitchell Island showed that permanent shallow flooding to a depth of about one foot resulted in a net accumulation of carbon which lead to the accumulation of approximately 1 to 2 inches of biomass per year.

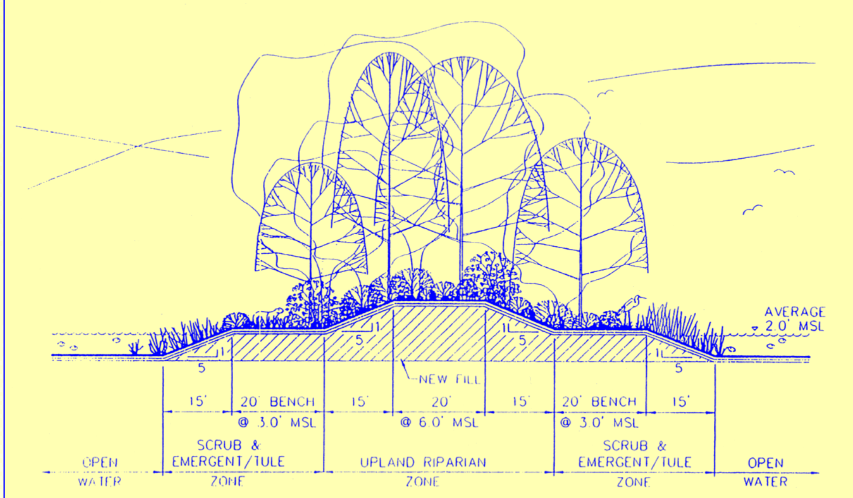
PROJECT IN ACTION

Flooding & Restoring Prospect Island

The Prospect Island Restoration Project will restore approximately 1,200 acres of shallow-water tidal wetlands and aquatic habitat, as well as about 130 acres of upland riparian habitat. Hoped-for benefits of the project include the creation of spawning and rearing habitat for fish, habitat for resident and migrating waterfowl and shorebirds, and contributions of plankton and organic carbon to Delta channels. The completed project will be incorporated into a North Delta Wildlife Refuge, which will also include Liberty Island and Little Holland Tract.

The island lies in the northwestern part of the Delta and is bounded by the Sacramento River Deepwater Ship Channel, the remnants of Little Holland Tract and Miner Slough. Construction plans include building eleven islands (varying from 120 to 180 feet in length), excavating a deep central channel (5-feet deep by 300 feet wide), creating 6 dead-end slough channels (3-feet deep by 60-feet wide), extending inboard levee benches to 40 feet and creating two 300-foot levee breaches on the perimeter of the island. The two levee breaches will be at the southern end of the island allowing for tidal exchange of the waters of the flooded island. The purpose of the new islands is to decrease

Typical Restored Island Section



wind fetch lengths and maximize the land/water edge. All fill materials for the islands and the embankments will come from the central channel, which should help create a flow-through system. Plantings will be used to protect levees and islands against erosion and create shaded riverine aquatic habitat.

Staff have developed a monitoring plan for the project to provide information to guide future restoration projects in the Delta and to allow for adaptive management of the project. Project construction is scheduled to begin in 2000 (Winternitz et al., SOE Poster, 1999).

Participants: California Department of Water Resources, California Department of Fish & Game, U.S. Army Corps of Engineers, U.S. Fish & Wildlife Service, California Urban Water Agencies, and the CALFED Bay-Delta Category III Program, Bureau of Reclamation.

➤ MORE INFO? czemitis@water.ca.gov

REHAB ADVICE

- Conduct more research into techniques for reversing subsidence, as a step towards restoration. Such techniques might include shallow flooding and bioaccretion (as water surface is raised, the tule marshes lay down and become mattes, forming the basis of new peat soils) and the addition of new material to island surfaces (dredged material, rice straw, etc.).
- Develop a continuous sea-level migratory corridor through the Delta of freshwater marshes of all gradients, which connects Suisun Marsh to riparian riverine habitats such as the Cosumnes on the Delta's east side.
- Continue restoration projects that set existing levees back away from rivers, protect remnant channel islands, build new channel islands, restore flooded islands and the peripheral Delta islands, establish habitat on levees, and restore deeply subsided interior Delta islands (Schmutte, SOE, 1999).

PROJECT IN ACTION

Politics of Creating a Refuge

In the course of establishing Stone Lakes National Wildlife Refuge in Sacramento County and planning for establishment of the proposed North Delta NWR, staff of the U.S. Fish and Wildlife Service have become familiar with the socio-political environment of the northern Sacramento-San Joaquin Delta. The Stone Lakes Basin lies 10 miles south of Sacramento, east of the Sacramento River, and supports native grasslands, seasonal and permanent wetlands, riparian forest, and several permanent lakes. The basin provides habitat for significant populations of migratory water birds and several special status species, and is experiencing rapid urban development and conversion of land to vineyards.

The Stone Lakes refuge was established in 1994 and has a goal of protecting 18,000 acres of fish and wildlife habitats, including maintaining 10,000 acres of existing agricultural lands. To date, the project has successfully protected 2,500 acres through acquisition by the Service and cooperative agreements with local and state agencies who own another 3,400 acres within the project boundary. The planning process for creating Stone Lakes NWR entailed extensive public participation and preparation of an environmental impact statement that successfully withstood legal challenge. Opposition to the project came primarily from local landowners, developers, winery interests, and recreational boaters. Among the issues raised related to federal ownership or joint management of lands, were: potential use of condemnation, mosquitoes and public health, continued use of navigable waterways, potential effects on county tax revenues, wetland development and flood risk, refuge maintenance funding levels, and perceived conflicts between farming and restoration of wetlands and endangered species. As the planning process progressed and as the refuge became established, nearly all these issues were resolved or never materialized.

In 1997, the Service began planning for establishment of the proposed North Delta National Wildlife Refuge in the southern Yolo Bypass in Yolo and Solano counties. This project builds on ongoing collaboration among many agencies for restoration/acquisition of Prospect Island and Little Holland Tract in the northern Delta (see opposite). It also contributes to a number of ongoing regional planning efforts such as: the Ecosystem Restoration Strategic Plan for the CALFED Bay-Delta Program, the Central Valley Habitat Joint Venture of the North American Waterfowl Management Plan, the Yolo County Habitat Conservation Plan, and activities of the Yolo Basin Foundation, Solano County Farmland & Open Space Foundation, and The Nature Conservancy. The project would contribute to the recovery of native Delta fishes and wintering waterfowl, restoration of native plant communities, and improved conveyance of floodwaters through the Yolo Bypass. In response to interest in the project by willing landowners, the Service recently expanded the study area for the project to 47,000 acres. A draft environmental assessment identifying the preferred boundary for the North Delta refuge was released for public comment in April 1999. Among the many issues raised during the scoping phase for planning the project have been: economic effects of converting agricultural land to habitat; relationship of this project to CALFED; hydrologic effects of tidal restoration; effects on county tax revenues; access for recreational boating, fishing, and waterfowl hunting; potential screening of diversions; Rio Vista flood protection; waterfowl depredation on crops; and project effects on land values (Harvey, SOE, 1999)

➤ MORE INFO?
Thomas_Harvey@mail.fws.gov

Courtesy: USFWS

ENDANGERED FISH

Peter B. Moyle, University of California, Davis

The Estuary is home to many native aquatic species, most of them in decline. Best known are the fishes, of which some are extinct, several are listed as threatened or endangered, and others are in the pipeline for listing.

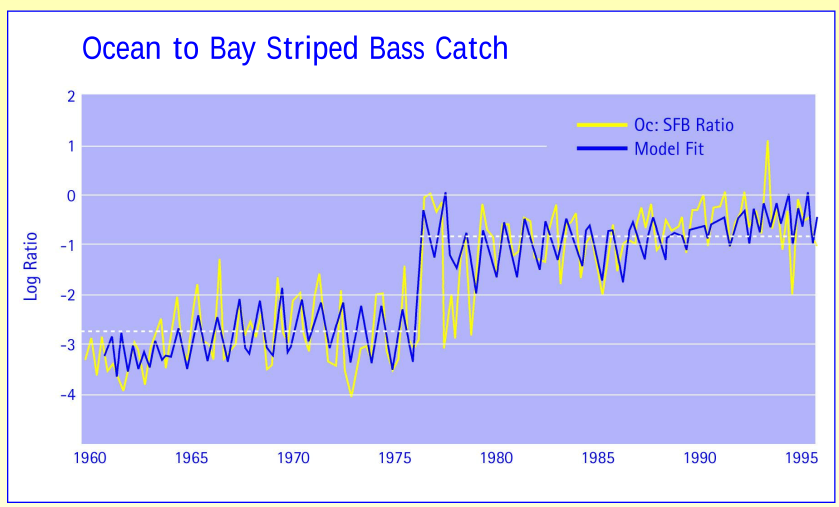
The Delta Native Fishes Recovery Plan (completed in 1993 but issued by U.S. Fish & Wildlife in 1996) evaluated the status of seven declining native species that require a wide variety of conditions. The present status of these species, plus the winter run Chinook salmon, provide a good indication of estuarine conditions. Of the eight species, we don't know what is going on with green sturgeon, Delta smelt show no sign of recovery, longfin smelt are doing a little better, and the remaining five species have shown improvement in their numbers in last five years. The improved status of the species is the result of an unusual series of wet years. Splittail, salmon, and maybe longfin smelt, have had strong positive responses to increased flows in rivers and increased outflow. These species are still not recovered, however. Return of drought conditions with high rates of diversion is likely to cause their numbers to plummet again. However, the wet years have bought us some time to deal with restoration issues.

Rehabilitation of these species and other aquatic biota in the Estuary will require major changes in the way we manage the Estuary and its watershed. Because of the extensive establishment of non-native species and massive changes to the region's land and water, restoration of the original ecosystems and habitats is not possible. It should nevertheless be possible to manage the system in ways that favor the development of naturalized ecosystems that are dominated by native species and that resemble the original systems in many of their ecological and aesthetic attributes. We are currently in the midst of an unusual "window of opportunity" to recover species, habitats and ecosystems in this region. Ever since the Bay-Delta Accord was signed, Nature has cooperated and bought us some time. We must continue to take advantage of the time granted us and make some serious commitments to conservation before the next major drought hits, as it surely will.

NEW SCIENCE

Climate Change and Striped Bass

Large-scale climatic effects can impede rehabilitation efforts aimed at local issues within the Estuary, among them preservation of the popular striped bass population. Striped bass — a non-native species used for many years as an indicator of estuarine health — declined sharply in 1976-1977. The decline has been attributed to impacts of freshwater exports for human use on young fish. This research, however, examined the hypothesis that the decline is related to a period of frequent El Niños and a concurrent shift in the atmosphere-ocean climate beginning in 1976-1977. The research shows that older striped bass migrated to the warmer Pacific Ocean during frequent El Niños after 1976, reverting to the behavior of native Atlantic populations. Time series analyses indicate that the step-like decline in estuarine striped bass abundance is associated with a step-like increase in ocean temperature. In addition, researchers correlated ocean temperature with the higher occurrence of older striped bass in the ocean and the mortality rate of adults in the Estuary. The resulting reduction in egg abundance due to the loss of older females from the Estuary correlates with declining recruitment of three-year-old bass to the adult sport fishery. These results implicate warming ocean conditions as an important factor in striped bass abundance, and suggest that future rehabilitation efforts should address potential effects of ocean conditions on the movements and survival of striped bass (Bennett & Howard, SOE Poster, 1999).



➤ MORE INFO?
wabennett@ucdavis.edu

REHAB ADVICE

- Improve management of existing flood plains and re-establish more flood plain habitat. Manage the Yolo and Sutter by-passes to favor salmon, splittail, and other fishes.
- Establish more natural hydrological regimes in stream and river systems. If natural flow regimes can't be re-established, then mimic them.
- Improve fish access to upstream habitats.
- Prevent further invasions by exotic species. Stop ships from releasing foreign ballast water into the Delta and Estuary.
- Assure that whatever options are adopted by CALFED do no further harm to native organisms (Moyle, SOE, 1999).

➤ MORE INFO? pbmoyle@ucdavis.edu

PROJECT IN ACTION

New Flow Regime for Tuolumne Salmon

One of the most significant improvements in the flow regimes of Bay-Delta tributaries for the sake of fish began being implemented in summer 1996 as a result of a settlement agreement concerning operation of Don Pedro Dam on the Tuolumne River. This 1995 agreement, the product of four years of evaluation and mediation under the Federal Energy Regulatory Commission's (FERC) dam licensing process, revised stream flow requirements in place for over two decades, required habitat restoration to improve conditions for Chinook salmon, and ordered additional monitoring of habitat and fish to evaluate flow and non-flow measures. The agreement was signed by a group of 11 state and federal agencies, water suppliers, and environmental groups. It also set up a multi-interest technical advisory committee which has since produced a habitat restoration plan for the entire lower Tuolumne River corridor (see p. 26), and remains deeply involved in decisionmaking concerning river management and improvement projects. The committee also works with a Cal Fish & Game biologist now assigned full time to the Tuolumne River.

In terms of the flow regime, the agreement and the new FERC order increased stream flows down the Tuolumne across the board for all year types. Prior to 1996, minimum flows for salmon in the river ranged from 40,000 to 123,000 acre feet per year. Under the new license order, minimum in-stream flows must range from 94,000 to 301,000 acre feet per year, depending on the water year type. This flow increase provides for higher spring pulse flows to help fall-run smolts on their outmigration back to sea, and for significantly higher summer flows. Fall flows are similar to those required under the old license. Despite these new demands on Tuolumne water, over half the average 1.9 million acre feet of runoff in the river basin will continue to be diverted for agricultural and municipal use. But the new regime should help the river's salmon run, whose numbers dropped to a mere few hundred fish during the 1988-1992 drought.

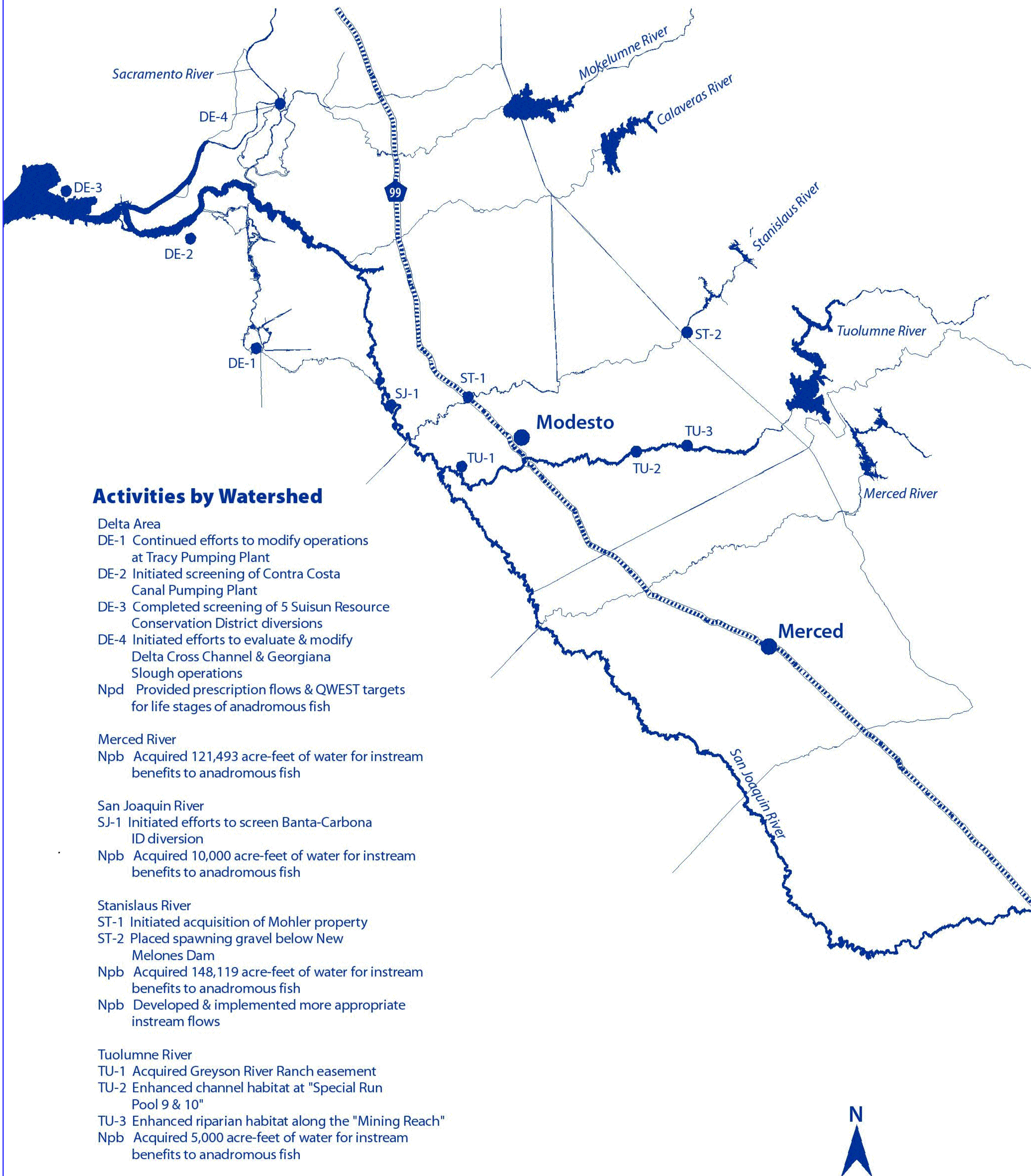
Although the agreement made landmark changes in how the river is managed, particularly in dry years when fish most need the water, the two wetter years since 1996 have made it relatively painless to implement to date (Ford, Pers. Comm., 2000). For more info on restoration projects benefiting anadromous fish see pps. 24, 26, 28, 29, 31, 32, 36 and 37.

Participants: California Department of Fish & Game, California Sports Fish Protection Alliance, City & County of San Francisco, FERC, Friends of the Tuolumne, Modesto Irrigation District, San Francisco Bay Area Water Users Association, Tuolumne River Expeditions, Tuolumne River Preservation Trust, Turlock Irrigation District, U.S. Fish & Wildlife Service.

➤ MORE INFO? tjford@tid.org

Courtesy McBain & Trush

CVPIA Anadromous Fish Restoration Activities
in the San Joaquin River Basin and Delta Area, 1993-1998



Activities by Watershed

Delta Area
DE-1 Continued efforts to modify operations at Tracy Pumping Plant
DE-2 Initiated screening of Contra Costa Canal Pumping Plant
DE-3 Completed screening of 5 Suisun Resource Conservation District diversions
DE-4 Initiated efforts to evaluate & modify Delta Cross Channel & Georgiana Slough operations
Npd Provided prescription flows & QWEST targets for life stages of anadromous fish

Merced River
Npb Acquired 121,493 acre-feet of water for instream benefits to anadromous fish

San Joaquin River
SJ-1 Initiated efforts to screen Banta-Carbona ID diversion
Npb Acquired 10,000 acre-feet of water for instream benefits to anadromous fish

Stanislaus River
ST-1 Initiated acquisition of Mohler property
ST-2 Placed spawning gravel below New Melones Dam
Npb Acquired 148,119 acre-feet of water for instream benefits to anadromous fish
Npb Developed & implemented more appropriate instream flows

Tuolumne River
TU-1 Acquired Greyson River Ranch easement
TU-2 Enhanced channel habitat at "Special Run Pool 9 & 10"
TU-3 Enhanced riparian habitat along the "Mining Reach"
Npb Acquired 5,000 acre-feet of water for instream benefits to anadromous fish

Npb = NonPoint-Specific Benefit

CVPIA Anadromous Fish Restoration Activities on Sacramento River and Tributaries,1993-1998

Activities by Watershed

American River
- AM-1 Reconfigured Folsom Dam shutters for temperature control
- Npd Initiated program to replenish spawning gravel
- Npd Developed & implemented more appropriate instream flows

Antelope Creek
- AN-1 Completed flow & temperature gage installation
- Npd Funded increased enforcement of regulations

Battle Creek
- BA-1 Completed ozonation, interim screening of diversion and upstream ladder improvements at Coleman NFH, and instream work helping to prevent spring-run hybridization
- Npd Acquired a total of 29,950 acre-feet of water for instream uses

Big Chico Creek
- BC-1 Acquired Peterson property
- BC-2 Relocated M&T diversion
- BC-3 Completed flow & temperature gage installation
- BC-4 Installed bypass structure at One-mile Pool
- Npd Eliminated M&T diversion; relocating to a screened diversion on the Sacramento River

Butte Creek
- BU-1, 2, 3, 4, 6, 13, 17 Completed flow & temperature gage installation
- BU-5 Implemented efforts to provide passage at Sanborn Slough bifurcation
- BU-7 Removed McPherin and McGowan dams
- BU-8 Removed two Western Canal dams
- BU-9 Completed siphon at Western Canal
- BU-10 Completed ladder and screen at Gorrill Dam
- BU-11 Completed ladder and screen at Rancho Esquon Partners Diversion Dam
- BU-12 Acquired Keeney property
- BU-14 Completed ladder and screen at Durham Mutual Dam
- BU-15 Completed screen at Parrott-Phelen Dam
- BU-16 Acquired McAmis property
- Npd Provided additional 40 cfs through water exchange

Clear Creek
- CL-1 Completed instream restoration activities reducing stranding
- CL-2 Initiated efforts to restore floodplain
- CL-3 Placed spawning gravel below McCormick-Saeltzer Dam
- CL-4 Completed flow & temperature gage installation
- CL-5 Placed spawning gravel below Whiskeytown Dam
- Npd Increased minimum instream flows between Oct to May
- Npd Continued efforts to control ersosion in watershed

Deer Creek
- DC-1 & 4 Completed flow & temperature gage installation
- DC-2 Acquired L&L Hamilton property
- DC-3 Acquired L&L Gaumer property

Feather River
- FE-1 Completed flow & temperature gage installation

Mill Creek
- MI-1 & 2 Completed flow & temperature gage installation
- MI-3 Acquired Birkes property
- MI-4 Converted groundwater pumps providing additional instream flows
- MI-5 Removed concrete from stream habitat
- MI-6 Acquired Dana 1 property
- MI-7 Acquired Latimer property
- Npd Initiated pilot riparian restoration demonstration program

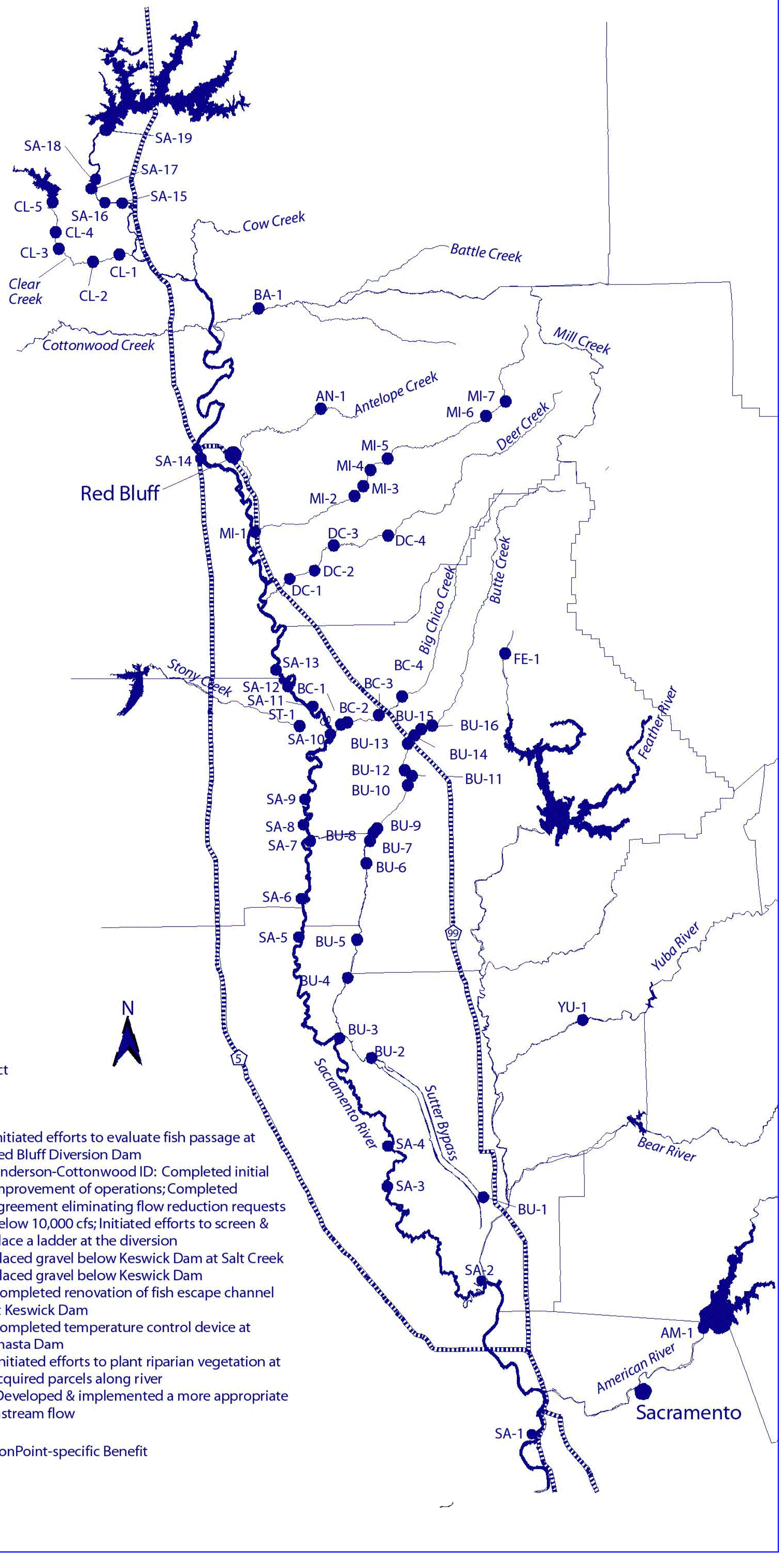
Stony Creek
- ST-1 Nearly completed installation of siphon on Stony Creek

Yuba River
- YU-1 Nearly completed fish screen at Browns Valley Irrigation District

Activities Along The River Corridor

- SA-1 Acquired property at Chicory Bend
- SA-2 Completed flow & temperature gage installation
- SA-3 Completed screening of Pelger-Mutual Water Company diversion
- SA-4 Completed screening of Reclamation District 108 diversion
- SA-5 Completed screening of Maxwell ID diversion
- SA-6 Completed screening of Reclamation District 1004 diversion
- SA-7 Acquired property at Hartley Island
- SA-8 Near completion of screen at Princeton-Cordora-Glenn/Provident ID diversion
- SA-9 Acquired Millar Farms property
- SA-10 Completed screening M&T Ranch diversion
- SA-11 Acquired Pine Creek Orchards property
- SA-12 Completed screening of Wilson Ranch diversion
- SA-13 Continued effort to screen Glenn-Colusa ID diversion
- SA-14 Initiated efforts to evaluate fish passage at Red Bluff Diversion Dam
- SA-15 Anderson-Cottonwood ID: Completed initial improvement of operations; Completed agreement eliminating flow reduction requests below 10,000 cfs; Initiated efforts to screen & place a ladder at the diversion
- SA-16 Placed gravel below Keswick Dam at Salt Creek
- SA-17 Placed gravel below Keswick Dam
- SA-18 Completed renovation of fish escape channel at Keswick Dam
- SA-19 Completed temperature control device at Shasta Dam
- Npb Initiated efforts to plant riparian vegetation at acquired parcels along river
- Npb Developed & implemented a more appropriate instream flow

Npb = NonPoint-specific Benefit



PERSPECTIVE

A Century of Failed Hatchery Policies

Michael Black
Historian & Policy Analyst

Western fish and fisheries, together with indigenous peoples, were among the first victims of water mobilization in California and they remain among the species most endangered today. They are victims not only of the rapid alteration of California's hydrology and landscapes to move water from where it naturally goes to where it is desired, but also of a legacy of failed 18th-century fisheries restoration policies.

"Federal and state-level assumptions governing fisheries policies in 1890 remain virtually unchanged to this day. "

For well over a century, Californians have sought to compensate for depleted salmon runs on the Sacramento River by creating fish hatcheries. Fish culturalist Livingston Stone located the West's first fish hatchery on the lower McCloud River in 1872, on the eve of nation's first ecological crusade when genteel fish breeders in the Northeast were seeking to restore anadromous shad and Atlantic salmon to the Merrimack, Connecticut and Delaware rivers.

Throughout the 18th and 19th centuries, New Englanders decried the loss of Atlantic salmon, shad and other anadromous fishes throughout the region's rivers. The familiar litany of human affronts like deforestation, overgrazing, canal and dam building, industrialization, urbanization, waterborne pollution and rapacious overharvesting each undermined returning stocks of fish. Increasingly nostalgic for what was missing, many Yankees watched in horror as an Arcadian countryside of forests and glades was shredded and harnessed to fuel congested, noisy and polluted industrial centers.

In May 1853, Nathan G. Fish presented to Connecticut's General Assembly a report aimed at fishery restoration. Salmon, trout and pickerel, among other species, were singled out to restock the state's flagging fisheries by means of artificial propagation. Rather than reigning in adverse human behavior toward dwindling fishes, Mr. Fish cited French governmental efforts at artificial propagation (Fish 1853). Whigs reckoned that distasteful affronts toward liberty could be avoided by substituting a plan to reindustrialize nature.

Three years later, George Perkins Marsh spelled out a solution to the inevitable collision between wo/man and nature. His 1857 report to Vermont Governor Ryland Fletcher foretold of "The final extinction of the larger wild quadrupeds and birds, as well as the diminution of fish, and other aquatic animals, [which] is everywhere a condition of advanced civilization and the increase and spread of rural and industrial population (Marsh 1857)." Instead of predicting a head-on collision between humans and nature, however, Marsh promoted resurrecting forgotten fish-breeding practices common to imperial Rome, monastic Europe, and ancient China.

Mindful of how poorly regulation faired in a laissez-faire world, Marsh urged Vermont's legislature to promote (rather than to restrict) the entrepreneurial and scientific talents of its fish breeders. He urged that they create a state Fish Commission to oversee the restoration of depleted fisheries. New laws should be enacted, Marsh advised, to protect the property of commercial fish breeders while new technology would usher in untold numbers of freshly minted fish. In a perfect tautology, naturalist Marsh believed that he could stave off a crisis fueled by regional industrialization through industrial fish cultural techniques.

Neither of the states of Vermont or Connecticut acted upon the recommendations of their restorationists. Following a traumatic Civil War, however, Marsh's advice was finally embraced. In 1864 the states of Vermont and New Hampshire appointed Fish Commissioners. They were soon followed by Massachusetts (1865), Connecticut (1866), California (1870) and many others.

In 1871, the Federal government was also drafted to intervene on behalf of exhausted fisheries. The Smithsonian Institution's Associate Director Spencer Fullerton Baird was drafted to head the U.S. Commission on Fish and Fisheries. Vermont Commissioner M.C. Edmunds suggested that one of the government's hatcheries be located on the West Coast where California's salmon ova could be harvested to fuel a northeastern salmon restoration effort.

In June 1872, Baird dispatched New Hampshire fish culturalist Livingston Stone to California to quarry fertilized salmon eggs for trans-shipment east. Stone built the West's first fish hatchery on the lower McCloud River. But following the collapse of California fisheries in 1884, as well as the blocking of salmon access to the McCloud River hatchery by the new Central Pacific Railroad, Baird saw no point in continuing Stone's propagation program out West and ordered it suspended. Shortly before his death in 1887, Baird acknowledged that adverse human practices were the principle killers of migratory salmon. By 1892, the Northeast's attempted salmon restoration was abandoned as a failure.

Within the next century, however, that mid-course correction was either buried or forgotten in California. Between the late 1800s and 1960, 169 significant public and private fish hatcheries and egg collection stations were operated throughout the state (Leitriz 1970). The most recent one, named for Livingston Stone himself, is located at the base of the Central Valley Project's keystone facility, Shasta Dam.

Today we find ourselves ensnared in a century-old environmental policy trap. The federal and state-level assumptions governing fisheries policies in 1890 remain virtually unchanged to this day. What we observe is a century of escalating conservation efforts (Band-Aid solutions like hatcheries) measurable in declining numbers of wild fish.

Instead of benefiting salmon populations, biologist Ray Hilborn argues that hatchery programs "may pose the single greatest threat to the long-term maintenance of salmonids" (Hilborn 1992). Despite mounting evidence that domesticated and wild fish are incompatible, costly hatcheries continue to be thrown at dwindling numbers of endangered species.

Hatcheries best exemplify the regrettable sequence of plausible but unworkable assumptions that still guide state and federal fisheries policies (Black 1994). From the outset, those entrusted with overseeing the West's declining fisheries have tailored their objectives to comply with market attitudes and behavior. Rather than challenge the profitable destruction of western rivers, institutional policies begot a compensatory holding pattern. I refer to this lineage of fish rescue strategies as "serialistic policies."

Serialistic policy is a deliberately muddled pattern of agency policy goal substitution and decay, followed by the overlay of a fresh batch of technical fixes and their subsequent failure. It occurs when agencies lack sufficient power to restrain market driven overexploitation of limited resources, like water. Rather than reigning in economic actors profiting at ecosystem expense, managers treat the ecological instability that results through technological means including hatcheries, fish ladders, barges, acoustic fish screens and a panoply of gizmos. As with our 19th century predecessors, if we remain trapped by such logic, we will never have enough money — or glue — to reassemble our watersheds.

Ecosystems, like Humpty Dumpty, are vastly easier to protect than they are to reassemble. (Black, SOE, 1999).

➤ MORE INFO? michaelb@igc.org

GROUNDWATER

Neil M. Dubrovsky, U.S. Geological Survey

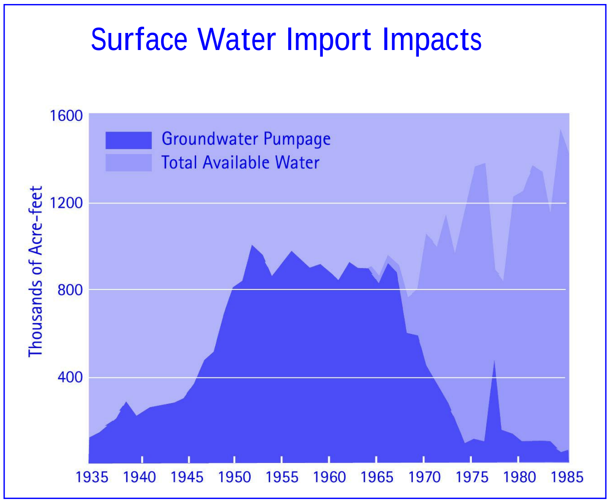
Surface water from rivers, streams, reservoirs and wetlands is only a small, but visible, part of the mass of water in the Central Valley; most of the fresh water is groundwater in aquifers. The debate on how to improve management of our water resources has evolved to the point where these two parts of the water budget are being more fully integrated. Meanwhile, much remains to be done to avoid actions that have damaged the groundwater resource in the past.

Under natural conditions the groundwater in the Central Valley was part of an integrated, hydrologic system extending from the drainage divide in the Sierra Nevada and Coast Ranges to San Francisco Bay. The groundwater system was recharged by infiltration of streamflow and rainfall. In turn, groundwater discharge supported extensive wetlands along the axis of the valley and sustained streamflow to the Delta in the dry months.

The Central Valley aquifers constitute an enormous storage compartment for freshwater, containing about 102 million acre-feet of useable storage, more than twice the amount of water stored in all major reservoirs statewide. The aquifer system has been extensively developed, with thousands of wells withdrawing an estimated 11 million acre-feet each year — about half the water use in the Central Valley. This resource also provides drinking water for much of the population of the Central Valley.

Development of water resources has radically altered the water budget of much of the valley, in many cases causing problems. In parts of the valley, groundwater is now recharged primarily by infiltration of irrigation water and discharged primarily by pumping. The altitude of the water table has decreased over large areas because of increased groundwater discharge by pumping.

A decrease in the water table altitude means greater pumping costs, less water in storage, a decrease in the groundwater discharge that supports wetlands and streamflow, and potentially degraded water quality. In the western San Joaquin Valley, this decrease in water table altitude has resulted in extensive land subsidence, causing structural damage and permanent loss of groundwater storage capacity. In some of these same areas, the water table is now too shallow, causing soil salinization. This is the result of another shift in the water budget — a massive decrease in groundwater discharge (pumping) that occurred when surface water was imported (see chart). This import also brought more water into the Central Valley than was there naturally.



Groundwater pumpage and total available water, Westlands Water District, San Joaquin Valley. Source: Belitz, Kenneth and Heimes, F.J., 1990

In addition to these physical changes in the aquifers, groundwater quality has been degraded by naturally occurring and man-made contaminants in both agricultural and urban areas (many Central Valley wells exceed guidelines for nitrate, and up to 60% contain pesticide residues, for example). Some of these contaminants are easily removed by water treatment, some are not, and many will persist for decades longer.

REHAB ADVICE

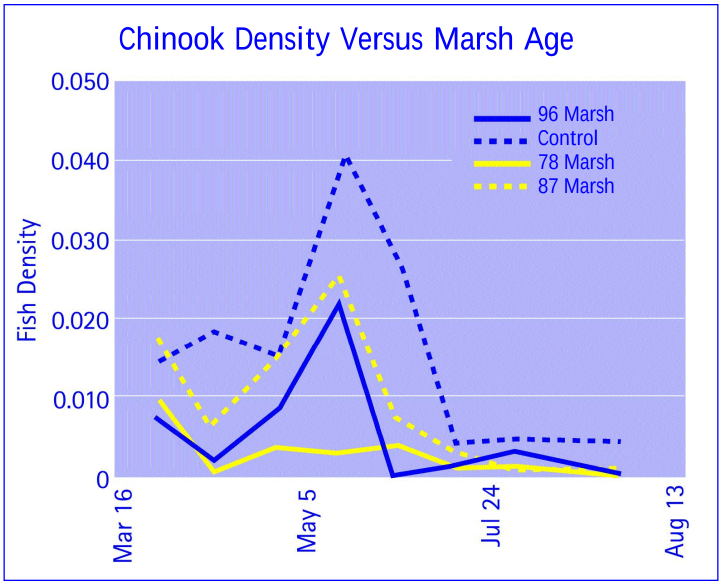
- Practice preventive medicine. Avoid past mistakes. Massive draw-downs of groundwater have led to massive subsidence in many areas, which is irreversible. Likewise the only remediation for many water quality problems is to simply wait for them to naturally disperse or degrade *in situ*.
- Add water back into aquifers where the water table has dropped hundreds of feet. Such increases in head space in our aquifers offer good opportunities for storage — underground storage that is more reliable and beneficial than that afforded by reservoirs because there is no evaporation, no seismic risk to communities downstream, and no drowning of miles of riparian habitat. Bringing the water table back up can also help restore some of that natural function where the groundwater is supporting the surface water ecology in wetlands.
- Consider pumping more groundwater in areas where the water table is shallower than it once was, and is thus accumulating salts and trace elements.
- Get regular check-ups. Collect and evaluate the data needed to measure the health of our groundwater system.
- Lead of balanced lifestyle. Manage groundwater and surface water together rather than independently to optimize beneficial use (Dubrovsky, SOE, 1999).

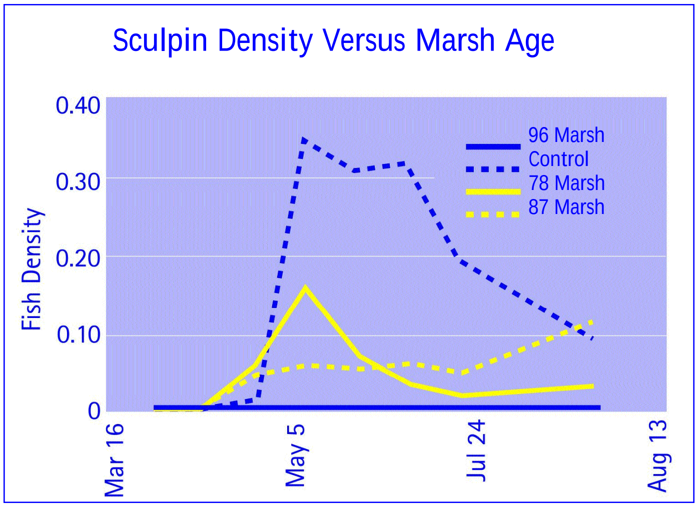
➤ MORE INFO? nmdubrov@usgs.gov

TIDAL WETLAND RESTORATION
PROMISE & UNCERTAINTY

Charles A. Simenstad, University of Washington

Within a decade, tidal marsh restoration in the Pacific Northwest has transcended rapidly from relatively improvised compensatory mitigation for wetland loss to ecosystem-scale initiatives for public-funded, non-compensatory recovery of important fish and wildlife habitat and other ecological, hydrological and cultural functions. This suggests that our technical ability to restore tidal marshes, and to accurately assess their functional response, has become increasingly more effective. However, as many critiques have noted, our efforts often have led to only partial success, if not abject failure — a present conundrum of tidal wetland restoration, which, despite its obvious promise, has yet to appreciably lower the uncertainty of the outcome.





Densities of juvenile chinook (top right graph; Oncorhynchus tshawytscha*) and Pacific staghorn sculpin (bottom;* Leptocottus armatus*) in Salmon River estuary marshes of differing restoration ages (dikes breached in 1978, 1987 and 1996) and undiked reference (control) marsh in 1998. Unpublished data from D. Bottom (NMFS-Newport) and T. Cornwell (ODFW-Corvallis).*

There are some clearly promising things about restoration:

- **Restoration happens**: Natural marsh restoration is readily apparent by the mature state of many marshes in the Pacific Northwest that have been restored without human intervention.
- **Marsh-building processes persist**: To a large degree, underlying processes are still operative if often moderated — salinity regimes remain, suspended material still provides minerals and organic matter for accretion, and plant and animal recruitment is pervasive.
- **Many functions respond rapidly**: While some functions require lengthy processes, the return of the tide often promotes rapid functionality, as in an increased tidal prism contributing to floodwater storage and to habitat and food web support for important resources such as salmon.

NEW SCIENCE

Comparing Restored Tidal Marshes of Varying Ages

An investigation comparing three tidal wetland restoration sites with a natural marsh indicates that biological communities in restored wetlands have different rates of establishment and that similarity to natural marshes may take a considerable period of time to evolve. The study investigated changes in soil characteristics and biological community heterogeneity at four wetland sites: a 3 month-old Caltrans mitigation site in the Albany mudflat; a 7-year-old channel at the Corde Madera Ecological Reserve; a 13-year-old mitigation site (Lincoln Properties) in Richardson Bay; and the 3-4,000 year-old Hoffman Marsh. Wetland functions and attributes evaluated included soil bulk density, organic content and particle size distribution; vegetative community heterogeneity and plant biomass; benthic community heterogeneity; and fish utilization of tidal channels. Samples were taken in October 1998 within the tidal channel, along the channel edge, and in the high marsh; aerial photographs helped with biomass evaluation and blocking nets and beach seine with fish samples. Results indicated that wetland functions within restored marshes exhibited temporal and spatial variation with increasing age. Some functions (such as bulk density and vegetative biomass) approached that of natural marshes within a relatively short period of time. Other functions (such as organic matter development and benthic community structure) increased steadily over the 13 years observed in this study, but were not similar to the natural marsh. Some functions (such as fish use) do not appear to be related to marsh age but to geomorphic features and proximity to other habitats (Buisson et al, SOE Poster, 1999).

➤ MORE INFO?
laura_castellini@nps.gov

REHAB ADVICE

- Avoid functional forcing. Designing restoration for one or two functions (e.g. designing habitats rather than ecosystems) is risky. Despite the pressing need to address threatened and endangered species, failing fisheries, and other arguments for tidal marsh restoration,unifunctional restoration restricts or prohibits the broader benefits of marshes.
- Give proper consideration to local and regional constraints. Interactions between structure (and function) and process are often overlooked, as is the fact that many critical processes have been irrevocably altered. Many projects pay insufficient attention to constrictions in the natural landscape, contaminant source control and non-indigenous species, which are prepared to pounce on new disturbances.
- Resist demands for instant gratification. We expect marshes to mature in far less time than natural processes allow. Understanding rate-limiting processes can prescribe approaches to accelerate development, but such intervention can be counterproductive because progression is often an essential precursor to functional equivalency.
- Avoid maladaptive monitoring. Monitoring response without evaluating underlying processes neither amplifies knowledge, nor leads to corrective actions (Simenstad, SOE, 1999).

Our challenge is to have appropriate science and engineering to evaluate trade-offs, and to know when, how, how long, and how much we must invest in intervention and control. Do we have the patience, the will, and the knowledge to incorporate science, rather than gardening, into tidal marsh restoration? What is the risk, particularly for recovering tidal marsh-dependent species like certain Pacific salmon stocks, of continuing to pursue our present ad hoc approach?

➤ MORE INFO? simenstd@u.washington.edu

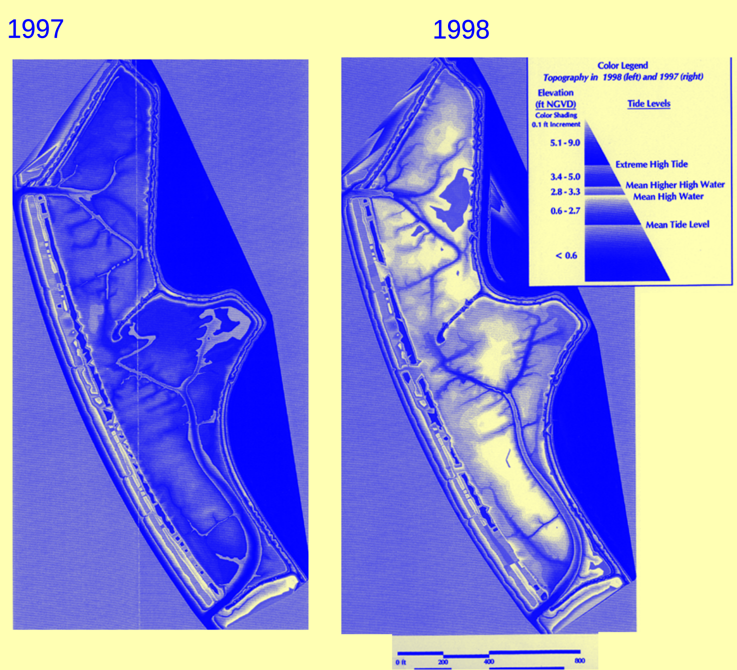
PROJECT IN ACTION

Geomorphic Processes in the Restored Petaluma River Marsh

Monitoring of the 45-acre Petaluma River Marsh site — restored to tidal action in 1994 — indicates a fairly rapid pace of evolution, underlining the importance of site location and associated geomorphic processes in selecting and designing wetland restoration projects. In the four and a half years since the Petaluma Marsh levee was breached, nearly two meters (six feet) of sediment have accumulated on the sub-sided site. In addition, a tidal channel network has formed, vegetation now covers approximately 15% of the site, and at least four threatened or endangered wildlife species already use the marsh. Long-term sedimentation rates at the site are high, averaging half a meter per year (1.5 feet) since return to tidal action, with short-term rates over the 1997-1998 El Nino winter reaching nearly one meter per year (3 feet). These sedimentation rates reflect the estuarine position of the project site just upstream of the confluence of the Petaluma River and San Pablo Bay, the site's direct open tidal connection to the Petaluma River, and its shelter from open winds of San Pablo Bay — results suggesting the importance of considering site location and sediment sources, as well as the nature of the tidal connection between these sources when undertaking sediment-dependent restoration projects. The tidal channel network also plays an important role in formation of the marsh. Initial conditions included small pilot channels to guide where larger channels would form and a series of small parallel berms between which a high density of smaller tidal channels have now formed. The current channel network reflects initial conditions in several regards, suggesting design approaches to promote project goals (Siegel, SOE Poster, 1999).

➤ MORE INFO?
stuart@swampthing.org

Sediment Accumulation
(Digital Elevation Model Photograph)



BAYLANDS ECOSYSTEM HABITAT GOALS

Mike Monroe
U.S. Environmental Protection Agency

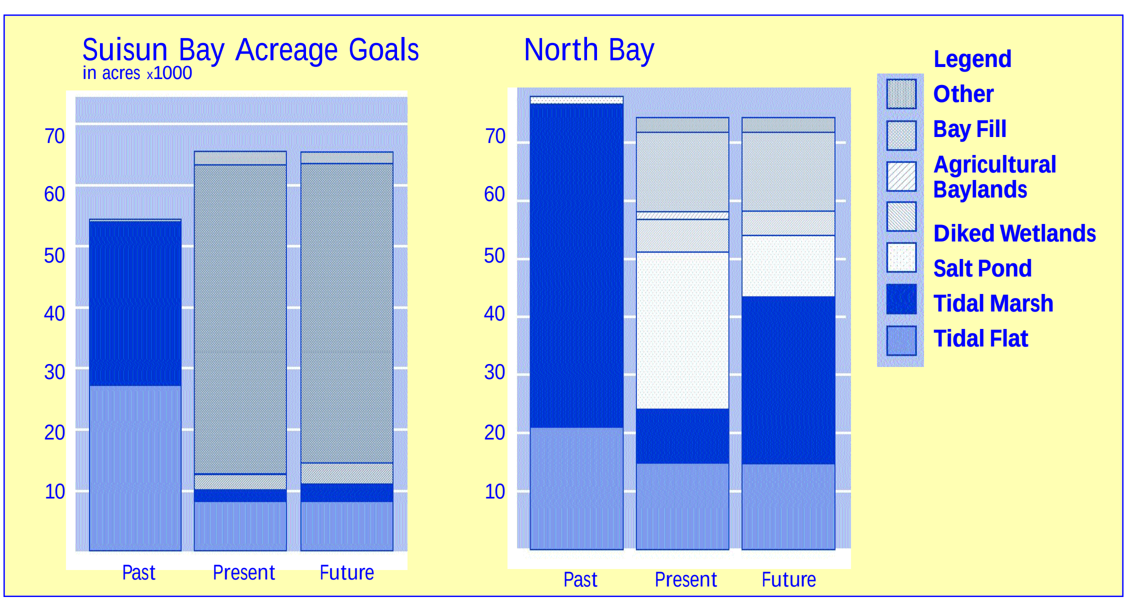
What kinds, amounts, and distribution of wetlands and related habitats are needed to sustain diverse and healthy communities of fish and wildlife resources in the San Francisco Bay Area? The answer to that question was developed after three years of work by more than 100 scientists, resource managers, and other participants in the San Francisco Bay Area Wetlands Ecosystem Goals Project (Goals Project),and released in a 1999 report at the State of the Estuary Conference.

The geographic scope of the Goals Project includes baylands — the lands within the historical and modern boundaries of the tides — in Suisun Bay, San Pablo Bay, and San Francisco Bay. To develop the Goals, participants selected key species and key habitats, assembled and evaluated information,prepared recommendations, and integrated recommendations into goals. In selecting key species, technical focus teams screened nearly 400 species of fish and wildlife and evaluated plant communities from the Bay to the adjacent uplands. The focus teams ultimately selected 120 species of invertebrates, fish,amphibians, reptiles, mammals, and birds to represent the complexity of the baylands ecosystem. In developing the list of key habitats, participants reviewed habitat lists created for previous wetland planning efforts. Ultimately, they designated some two dozen key habitats of the baylands ecosystem. After selecting key species and habitats, participants assembled qualitative and quantitative data on them,prepared initial habitat recommendations, and solicited public comment before releasing final Goals.

The Goals recommendations are founded on one important premise: no additional loss of wetlands within the baylands ecosystem. Furthermore, as filled or developed areas within the baylands become available, their potential for restoration to fish and wildlife habitat should be fully considered. In many areas, achieving the Goals will depend on the willingness of landowners to aid management and restoration efforts.

The specific recommendations of the Goals — which to suggest protection, restoration or enhancement of large areas of baylands habitat throughout the region — are summarized in the *Rehab Advice* section below, and in the charts.

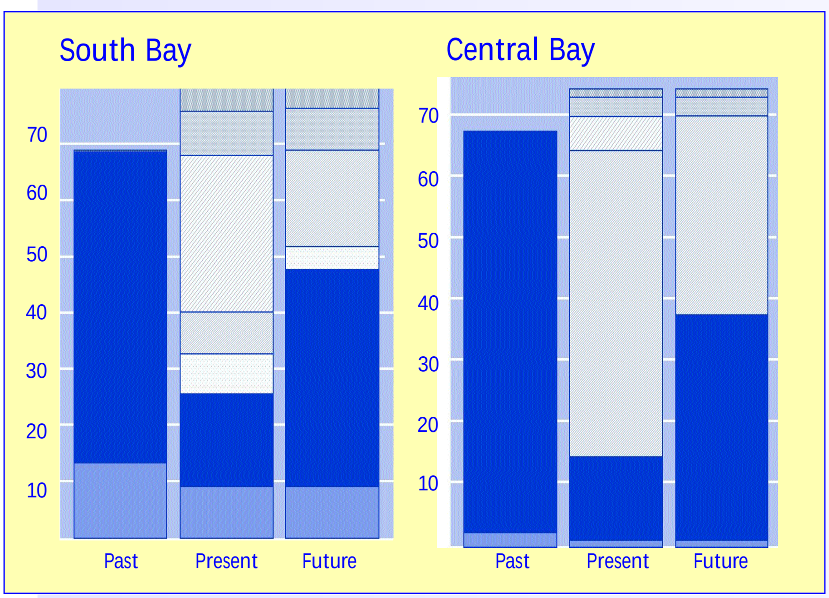
Achieving the Goals region-wide would have major environmental benefits — among them, the recovery of the baylands' many threatened and endangered species. Restoring large areas of tidal marsh would enable populations of salt marsh harvest mouse and California clapper rail to rebound, eliminating the need for their current special protection;improve habitat conditions for the endangered Chinook salmon and the threatened Delta smelt;improve the Bay's natural filtering system and enhance water quality; increase primary productivity of the aquatic ecosystem; and reduce the need for flood control and channel dredging. Likewise enhancing diked wetlands would increase the regional and subregional support of migratory birds. Restoring vernal pools and other seasonal wetlands would reverse declines of unique plant and animal communities. Restoring riparian corridors would benefit many species of amphibians, mammals, and birds.



REHAB ADVICE

REGIONAL LEVEL

- Provide many large patches of tidal marsh connected by corridors to enable the movement of small mammals and marsh-dependent birds; several large complexes of salt ponds managed for shorebirds and waterfowl; extensive areas of managed seasonal ponds;large expanses of managed marsh; continuous corridors of riparian vegetation along the Bay's tributary streams; restored beaches, natural salt ponds, and other unique habitats;intact patches of adjacent habitats, including grasslands, seasonal wetlands, and forests.
- Provide the approximate regional and subregional acreages for the key bayland habitats shown in the bar charts on these pages — keeping in mind that recommended changes should occur gradually over several decades.
- Offset losses of habitats converted to tidal marsh. To offset the conversion of salt pond habitat, the remaining salt ponds should be managed to maximize wildlife habitat functions, particularly for shorebirds, waterfowl,and other water birds. There should be salt pond complexes in North Bay and in South Bay adjacent to important shorebird foraging areas. Each complex should be managed to maintain a range of salinities and water depths that favor the desired bird species. To offset the conversion of agricultural bayland habitat, the remaining agricultural areas should be managed as seasonal pond habitat to improve habitat functions for shorebirds, waterfowl, and other water birds. To offset the conversion of managed marsh habitat, the remaining managed marshes should be managed to increase their waterfowl habitat functions.



- Address technical and policy issues arising from Goals implementation,including: phasing of projects so that the habitat functions of diked baylands — especially seasonal wetlands, salt ponds, and managed marsh — are provided when tidal marsh is restored;determining how and when to use dredged material for tidal marsh restoration; balancing the need for public access with the needs of bayland wildlife; controlling non-native invasive plants and introduced animal species; and ensuring adequate funding to acquire, restore, and manage bayland habitats in the long term.
- Establish a regional science program to support the management and restoration of the baylands ecosystem.
- Develop processes for landowners, agencies and the public to work together to achieve the Goals.

LOCAL LEVEL

Suisun

- Restore tidal marsh on the northern and southern sides of Suisun Bay, Grizzly Bay, and Honker Bay, and restore and enhance managed marsh, riparian forest, grassland, and other habitats.
- In Suisun Marsh, restore tidal marsh in a continuous band from the confluence of Montezuma Slough and the Sacramento/San Joaquin rivers to the Marsh's western edge. Extend this band of tidal marsh in an arc around the northern edge of the Marsh and blend naturally with the adjacent grasslands to provide maximum diversity of the upland ecotone, especially for plant communities.
- Restore a broad band of tidal marsh along the southern edge of Suisun Marsh and around Honker Bay, in large part to improve fish habitat.
- Continue the long-standing practice of managing diked wetlands primarily for waterfowl on the majority of lands within Suisun Marsh. Enhance these brackish marshes through protective management practices, to increase their ability to support waterfowl.
- Enhance moist grasslands with vernal pools on the periphery of Suisun Marsh,as well as riparian vegetation along the tributary streams.
- On the Contra Costa shoreline, restore full tidal action to many of the marshes that currently are diked or that receive muted tidal flow.
- Incorporate broad transition zones to foster a higher diversity of plant communities and associated animals.
- Provide buffers to protect these populations from adjacent disturbance. Restore riparian vegetation along as many stream corridors as possible.

North Bay

- Restore large areas of tidal marsh and enhance seasonal wetlands.
- Manage some of the inactive salt ponds to maximize their habitat functions for shorebirds and waterfowl,and restore others to tidal marsh.
- Protect and enhance tributary streams and riparian vegetation,and preserve and restore shallow subtidal habitats (including eelgrass beds in the southern extent of this subregion).
- Restore tidal marsh in a band along the bayshore, extending well into the watersheds of the subregion's three major tributaries — the Napa River, Sonoma Creek, and the Petaluma River.
- Improve seasonal wetlands in the areas currently managed as agricultural baylands.
- Protect and enhance all of the remaining seasonal wetlands in the uplands adjacent to the baylands.

Central Bay

- Protect and restore tidal marsh,seasonal wetlands, beach dunes, and islands.
- Restore natural salt ponds on the East Bay shoreline.
- Protect and enhance shallow subtidal habitats (including eelgrass beds).
- Protect and enhance tributary streams and riparian habitats.
- Restore tidal marshes wherever possible, particularly at locations that abut streams and at the upper reaches of dead-end sloughs. Encourage tidal marsh restoration in urban areas.
- Pursue opportunities to restore relatively small tidal marshes and other habitats, as topography and urban and industrial development limit the potential for large-scale habitat restoration in the Central Bay. Even small,disconnected patches of tidal marsh would provide habitat islands for migrating native wildlife species and improve overall habitat conditions. Even the smallest restoration efforts should try to incorporate transitions from intertidal habitats to adjacent uplands, as well as upland buffers, and to protect shorebird roosting sites.

PROJECT IN ACTION

Urban Marsh Restoration at Herons Head Park

Heron's Head Park, formerly known as Pier 98, is an urban greening project in its most dramatic form — ecological restoration of valuable shoreline property in an economically depressed neighborhood in one of the Bay Area's most populated cities. The park is located on a man-made peninsula created by the Port of San Francisco between 1970-1977 — via the placement of fill materials and construction debris — with the intent of providing either a container shipping terminal or the southern terminus of an additional Bay Bridge span. Work was never completed, and over time subsidence and inundation created three acres of tidal salt marsh along its southern shore. Enhancement of the existing wetlands and creation of five acres of new tidal salt marsh was completed in spring 1999.

The chosen design created new wetlands and a network of intertidal channels by removing fill soils and grading. Important design features are two small bird loafing and nesting islands that also provide refuge from high tides and predators, and a buffer from uplands areas. To create the refugia islands, the design took advantage of existing serpentine mounds placed there during construction of Highway 101. Naturally occurring serpentine contains high concentrations of trace minerals that can actually control invasive weedy plants.

The design also preserves and reinforces a unique assemblage of intertidal ponds that were essentially created by the fill and construction debris used to build the site. These ponds fill up with incoming flows on the higher tides and hold water during the outgoing tides, providing valuable bird habitat. In addition, the design enhances the newly-created transition zone between the wetland and upland areas. A local gardening group has initiated seed collection and propagation of transition zone plant species, many of which have become rare in the Bay Area as their habitat has been eliminated along with the salt marsh habitat.

In addition to ecological benefits, the Heron's Head Park design presents a rare piece of undeveloped shoreline — with established fishing and birdwatching opportunities — to a community which has little access to open space nearby. The design includes a new fishing pier, which provides a safe public fishing area while controlling damage to habitat and disturbance to wildlife. Local fishermen have long used the site, accessing areas adjacent the warm water P.G.&E. power plant outfall by walking through the wetlands.

The newly improved Heron's Head Park has and will provide myriad opportunities for community participation in wetlands enhancement. During the past year, more than 300 students, teachers, and community residents have participated in public programs at Heron's Head Park. In the future, the Port and the San Francisco League of Urban Gardeners will continue to educate community members and local students about natural resources conservation issues and techniques, while propagating, planting, and maintaining transition zone plants; City College of San Francisco will develop curricula around wetlands monitoring, including on-site activities for pre-kindergarten through college level courses; and the Southeast Alliance for Environmental Justice will hire and train local residents to lead public programs at Heron's Head Park (Levanthal, SOE Poster, 1999).

Participants: Port of San Francisco & San Francisco League of Urban Gardeners

Consultants: Levine-Fricke, AGS Inc., Keller-Mitchell, Inc, and Noble Consultants

➤ MORE INFO?
carol_bach@sfport.com

South Bay

- Restore large areas of tidal marsh connected by wide corridors of similar habitat along the perimeter of the Bay.
- Intersperse several large complexes of salt ponds, managed to optimize shorebird and waterfowl habitat functions, throughout the subregion,and restore naturalistic, unmanaged salt ponds on the East Bay shoreline.
- Provide and preserve natural transitions from mudflat through tidal marsh to adjacent uplands, wherever possible. Protect and improve adjacent moist grasslands, particularly those with vernal pools, for wildlife.
- Protect and restore riparian vegetation and willow groves wherever possible — see also p.22 (Goals Project, 1999).

➤ MORE INFO? pro@rb2.swrcb.ca.gov or www.sfei.org

NEW SCIENCE

Ecological Design Principles

The Goals Project recommends use of the following ecological design principles in bayland restoration plans.

- Center tidal marsh restoration, where possible, around existing populations of threatened and endangered species.
- Include restoration of tidal marsh along the salinity gradients of the Estuary and its tributaries.
- Emphasize restoring tidal marsh along the Bay edge and where streams enter the baylands.
- Provide natural features, such as pans and large tidal channels, within tidal marshes.
- Reestablish natural transitions from tidal flat through tidal marsh to upland, and between diked wetlands and adjacent uplands.
- Provide buffers on undeveloped adjacent lands to protect habitats from disturbance.

PERSPECTIVE

EFFECTS OF THE GOALS PROJECT

Joshua N. Collins
San Francisco Estuary Institute

The Bay Area Wetlands Ecosystem Goals Project has provided an answer to the question: how much of what kinds of wetlands are needed where to restore a healthy bay system? The answer emerged through a long examination of the ecological past, the present, and change. The answer is large-scale restoration and enhancement of the baylands in all four subregions, South Bay, Central Bay, North Bay and Suisun, in ways consistent with natural processes that control habitat evolution and maintenance. The project has also provided a venue for improved communications among environmental scientists working in the baylands.

The prospect of such an effort raises the next big question, how should the ideal be achieved? This is a political question with technical underpinnings.

All the technical questions relate to the central concept of the baylands as the transition between the bays and the uplands. Although this concept has been stated many times in the past, it is premiered as the central concept of the Goals Project. The focus provides a new view of the Estuary as a complex of many estuaries, with ecologically significant gradients of salinity and tidal effects running up and down every tributary creek and river. We can no longer view the baylands as just the edge of the bay, they are also the edge of watersheds. The Goals Project is calling attention to watersheds as the source of many environmental problems and solutions for the baylands and the Bay. Many technical questions arise from this new view. For example, will implementation of the Goals recover threatened and endangered species; will it increase tidal flushing and thus improve navigation; will it improve water quality; will there be enough sediment to build tidal marshes; do we start with tidal marsh restoration or diked bayland enhancement or both; and how big should projects be?

These are just a few of the many technical questions that project participants have raised. They seem to provide some detail on two larger questions: what is the relationship between level of baylands management or restoration effort and level of ecological function, and how is this relationship affected by natural processes and people in the attending watersheds. In simpler terms, we might ask, what are the cost breaks that make restoration and enhancement affordable, and what are the ecological thresholds that mean success?

The only way to answer these questions is to get started with a program of implementation that includes monitoring and research, such that we can learn by doing. There is a need to think big, move forward with measured steps, and question our assumptions and objectives all the way.

In the coming years, the San Francisco Estuary Institute will be working with other sources of technical help to develop a regional plan of baylands research and monitoring that can support the restoration and management of the baylands (Collins, SOE, 1999).

➤ MORE INFO? josh@sfei.org

TERRESTRIAL SPECIES
THE IMPORTANCE OF THE WETLAND-UPLAND INTERFACE

Lynne Trulio, San Jose State University

The terrestrial vertebrate species living at the edge of San Francisco Bay are important elements of the Bay's ecological functioning. The *Status and Trends Report for Wildlife* of the San Francisco Bay Estuary (1992) lists over 380 terrestrial vertebrates — amphibians, reptiles, birds and mammals — associated with the Bay in the counties immediately adjacent to the Bay and Delta. Although this diversity is impressive, since Europeans arrived many species have declined severely in abundance. At least 10 vertebrates have been extirpated from the region,including sea otters, pronghorn antelope, elk and California condors. Two species, the grizzly bear and grey wolf, have been eliminated from the entire state. The reintroduction and recovery of these species is a major restoration challenge.

People have also introduced at least 17 vertebrates to the region. Some, such as the wild turkey and ring-necked pheasant, fit into the local ecology without major ill effects. Others disrupt the ecology and cause havoc for native species. Exotic red foxes, for example, are known predators on endangered clapper rails and other ground nesting birds. Competition and predation by the non-native bullfrog has been one factor leading to the threatened status of the red-legged frog, once an abundant species.

Bay-Delta terrestrial species live in habitats from tidal salt marshes and riparian zones to grasslands and oak woodlands. The great majority of these species also use or depend upon transitional habitats, or ecotones, that connect the Bay-Delta wetlands with upland ecosystems.

Animals crossing this boundary connect wetland and upland ecosystems through interactions such as predation and competition. An ecotone is a dynamic gradient between adjacent ecosystems across which materials and energy flow. Definitions of ecotones emphasize their transitional qualities and dynamic nature.

Approximately half the San Francisco Bay edge is surrounded by Holocene era alluvial soils, which create a wide transitional zone between the tidal Bay-Delta and upland, terrestrial habitats. Alluvial soils support moist grassland/vernal pool habitats and riparian zones, two important Bay ecotones. Another vital transitional zone is the narrow high marsh area connecting the tidal zone and the terrestrial upland. According to data from the San Francisco Estuary Institute Eco-Atlas, approximately 74% of the alluvial soil habitats adjacent to the Bay have been lost (see table). Many restoration projects have been undertaken in riparian habitats, but moist grasslands have received very little restoration attention.

Ecotones are well known for their high biodiversity. They are very valuable to wetland species as they provide refugia from high tide events. Lack of protected high ground next to marshes has contributed to declines of rare salt marsh species such as black rails, clapper rails and salt marsh harvest mice. Transitional habitats pro-

NEW SCIENCE
Rail Habitat

Numerous Bay Area tidal marsh restoration projects attempt to provide habitat for the endangered California clapper rail, a largish, brown, secretive, pear-shaped bird whose Bay population is now estimated at only a little over a thousand birds (see p.12). High-quality clapper rail habitat needs full tidal circulation; a predominant pickleweed marsh with cordgrass, gumplant, and other high marsh plants; high marsh cover; and a well-developed system of tidal sloughs. Marsh restoration sites should be as large as the Dumbarton Marsh (118 ha) or Mowry Marsh (164 ha). Marshes should be within 1-3 km of each other, the distance clapper rails are known to disperse. Power lines, poles, and buildings provide perches for raptors and should be removed from restoration sites where possible. Because rubble piles and other structures can house Norway rats and feral cats, which prey on the rails, these should also be removed from marsh areas. Rails are susceptible to human disturbance, and recreation and maintenance activities should be carefully considered before being permitted on restoration sites. Restoration should also include management of non-native vegetation and predators like the red fox and feral cats; however, in the long run, only high-quality habitat will ensure an increase in clapper rail numbers. The restoration of Bair Island, a 1,600-acre former salt pond, holds promise for rail recovery because of its large size and proximity to another rail population on nearby Greco Island (Albertson & Evens, 1998).

The black rail also deserves the attention of restoration planners. Black rails need refuge from high-tides, at high elevations within the marsh where there is still tidal influence. Since connectivity with existing habitat could allow for better rail dispersal, restoration of smaller sites adjacent to occupied marshes such as the north shore of San Pablo Bay, and the entire south shore of Suisun Bay — particularly 5,000-plus acres near the Concord Naval Weapons Station — holds the greatest potential. Black rails are particularly sensitive to alterations in freshwater inflows, and rely on elevations just above the mean high water line, which are a little less saline and support a food web of terrestrial organisms the rails seem to rely upon (Evens 1997).

➤ MORE INFO? jevens@aol.com

vide food chain support to upland species, such as the burrowing owl and red-tailed hawk,and the presence of a wide buffer may prevent upland predators from foraging heavily in tidal marshes. Connecting upland and wetland ecosystems is considered critical to the proper functioning of the Bay-Delta (Goals Project, 1999). Over 80% of the Bay-Delta's special status species use or depend upon ecotonal areas.

Diking, filling, and dredging to support agriculture, industry and urban uses have all resulted in the loss of connections between the wetlands and uplands. A wide range of terrestrial species would benefit from the restoration of moist grassland, riparian and high marsh ecotones (see below). The recovery of these listed species depends on our ability to restore high quality connections between tidal marsh or stream zones and upland grasslands and woodlands.

What restoration work has been undertaken to help preserve and recover terrestrial species at the edge of the Bay? Numerous riparian zone and salt marsh restorations, particularly mitigation projects, have been implemented since the 1970s, when environmental regulations were enacted. Many of these projects are designed to restore habitat for rare or endangered species. However, there are no clear data on the overall results of these habitat restoration projects. Lack of monitoring has constrained our understanding of what procedures result in success or failure.

Monitoring of South San Francisco Bay salt marsh restoration projects, for example, has not been extensive enough to determine the effects on the clapper rail or salt marsh harvest mouse. However, habitat enhancement of the New Chicago Marsh in Alviso for the salt marsh harvest mouse has proven successful over the past 10 years. An example of successful clapper rail habitat restoration is the Avocet Marsh in Newark,undertaken by the staff of the Don Edwards San Francisco Bay National Wildlife Refuge. In 1985,salt marsh restoration was begun at a 100 acre former salt crystallizer pond next to Refuge Headquarters. In 13 years, this barren site was transformed into a functioning salt marsh that supports at least 5 clapper rails, 2 pairs and 1 single bird.

Past and Present Habitat Acreages for the San Francisco Bay Estuary:

Adjacent Habitats (data from Goals Project, 1999)

Habitat Type	Historical (ca. 1770-1820)	Present (ca. 1997)	% Change
Moist Grassland	60,487	7,474	-88%
Grassland/Vernal Pool	24,070	15,038	-38%
Riparian Forest	2,350	737	-69%
Willow Grove	2,547	37	-99%
Total	89,455	23,286	-74%

Since at least 90% of the original tidal salt marsh wetlands — cordgrass-pickleweed wetlands — have been destroyed, replacement of this ecosystem is a critical goal of restoration efforts around the Bay. However, we have begun to realize that species dependent on tidal marsh wetlands also require high tide escape zones and ecotonal buffer areas, if populations are to persist.

Several projects are now including transitional habitat to connect salt marsh restorations with adjacent uplands, including large projects at Oro Loma in Alameda County, Montezuma Wetlands in the Delta, Hamilton Airfield in Marin County (see p.49) and the Catellus Corporation restoration mitigation in Alameda County.

Much more can be done to restore terrestrial species. Planners and communities can do a better job preserving and restoring species by following the specific recommendations of the 1999 *Habitat Goals* report and other ecological planning documents. Communities should require that projects move out of the flood plain and high tide zones, rather than building right up to levees. Staying out

Terrestrial Species at the Edge

Some Species using Moist Grassland/Vernal Pool Ecotones

- CA Tiger Salamander (FC,SSC)
- Western Spadefoot Toad (SSC)
- SF Garter Snake (FE, SE)
- Short-eared Owl (SSC)
- Burrowing Owl (SSC)
- Snowy Plover (FT, SSC)
- Herons/Egrets
- Waterfowl/Shorebirds

Some Species using Riparian/ Willow Grove Ecotones

- Western Pond Turtle (SSC)
- CA Red-legged Frog (FT, SSC)
- Swainson's Hawk (ST)
- Long-eared Owl (SSC)
- Bank Swallow (ST)
- Willow Flycatcher (FE, SE)
- Salt Marsh Yellowthroat (SSC)
- Neotropical Migrants

Rare Vertebrates that Require Wetland/High Tidal Marsh Ecotones

- Salt Marsh Harvest Mouse (FE, SE)
- Ornate Shrew (FC1,SSC)
- Suisun Ornate Shrew (FC1,SSC)
- Salt Marsh Wandering Shrew (FC1,SSC)
- Alameda, San Pablo, Suisun Song Sparrows (SSC)
- California Clapper Rail (FE, SE)
- California Black Rail (FC1,ST)
- California Least Tern (FE, SE)

FT, FE = Federally Threatened, Federally Endangered
FC1 = Federal Candidate Species
ST, SE = California State Threatened, CA State Endangered
SSC = California State Species of Special Concern

of the flood plain reduces the chances of property damage and allows the restoration of rare riparian and seasonal wetland habitats. Planners can also work to include habitats for specific species in urban landscaping. Using native plant species and allowing important local species such as ground squirrels and voles to survive will provide more habitat for rare and declining species and will improve overall biodiversity.

REHAB ADVICE

General Terrestrial Species Recovery

- Realize that all restorations are experiments. Our predictive power is very low and systems may have multiple endpoints.
- Base restoration targets (measures of success) on the best model sites, historical information and modeling.
- Develop target ranges based on natural variability, measurement variability, multiple endpoints and uncertain constraints.
- Consider constraints on achieving ecosystem functioning/species recovery and modify success goals accordingly. Typical constraints are adjacent land uses (flood, fire constraints), human uses of site, site history (fill, toxics, draining, non-natives), lack of land (or money to buy it), lack of full complement of species, incomplete scientific data.
- Design experiments to test the reasons why species do or do not respond to restored sites.
- Monitor for long periods of time to determine long-term effects of restorations on species use, behavior, abundance and productivity.
- Monitor parameters to determine both species and ecosystem recovery.

Species-Specific Recovery

- Preserve remaining rare species habitats and transition zones.
- Target requirements of specific organisms within context of full habitat restoration.
- Restore as much habitat as possible, including transitions connecting upland and wetland ecosystems.
- Provide patches of habitat, as close together as possible, if contiguous habitat is not available.
- Find ways to connect the hydrology between patches.
- Recognize that levees create a hard edge around habitats that may be difficult for wildlife to cross.
- Manage remaining habitats to include gradients, habitat mosaics, ecological processes and biodiversity (Trulio, SOE, 1999).

➤ MORE INFO? ltrulio@annap.infi.net

PROJECT IN ACTION

Habitat Mix at Hamilton Airfield

The Hamilton Wetlands Restoration Project will restore a diverse mix of wetland habitat to over 900 acres of diked baylands at the former Hamilton Army Airfield in Novato, Marin County for endangered and other wetlands species. The project will also beneficially reuse up to 11 million cubic yards of clean material from Bay dredging projects.

A conceptual design has been prepared for the restoration project that is based on the physical characteristics of the site and lessons learned from past restoration projects, including the nearby Sonoma Baylands Project. The design is for a landscape that gradually slopes from uplands to the Bay — much like the historic shoreline did — supporting large expanses of tidal and seasonal wetlands. To accomplish this, levees will be constructed around the subsided site to protect adjacent properties from flooding. The site will then be filled with clean material from Bay dredging projects to construct the upland and seasonal wetlands site features and to speed the formation of tidal wetlands. However, the material will be placed low enough in tidal areas to allow the wetlands to form naturally on sediments carried in on the tides. Salt pannes, a feature of historic Bay wetlands that flood only on spring tides, will be created at the margin of the tidal areas. In fact the project's design centers around developing transitional habitat areas such as seasonal wetlands and tidal pannes that will persist for a significant number of years and provide a continuous transition in habitat type from tidal areas to the adjacent uplands. These transitional areas will also serve as high tide refugia for local wildlife.

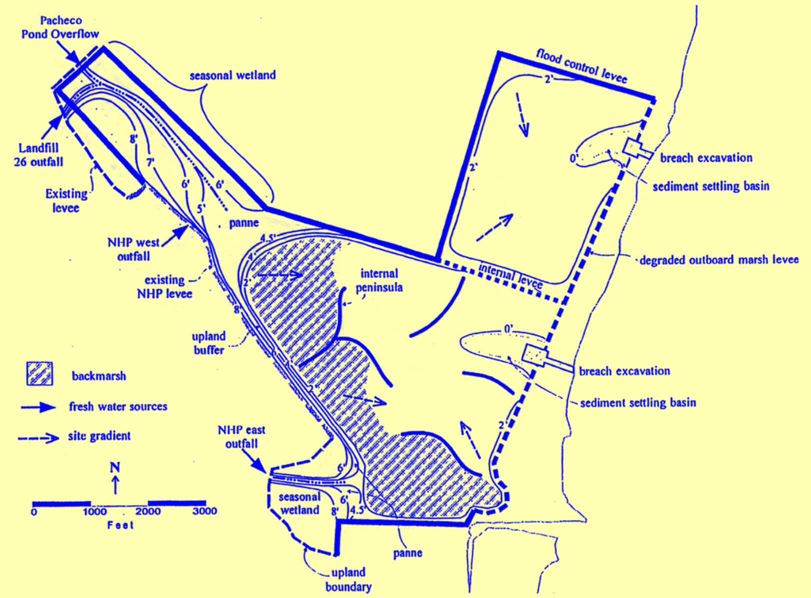
The result will be one of the largest contiguous tidal wetlands in the Bay. Two channels to the Bay, each over 200-feet wide, will restore tidal waters to the site. Plants and animals will colonize as the sediment-rich Bay waters build mudflats, and the ebb and flow of the tides cut a dense network of channels across the spreading tidal wetlands. The tidal areas will provide habitat for Bay fish species, including young endangered salmon making their journey to the ocean. The marsh channels will also be used by the endangered California clapper rail, while the pickleweed in the high marsh will be home to the endangered salt marsh harvest mouse. All the wetlands will be heavily used by a variety of shorebirds and waterfowl. Although the public will not be allowed into the sensitive habitat areas of the marsh, the Bay Trail will traverse the southern levee of the site and an overlook of the entire wetlands area will be provided on nearby Reservoir Hill (Goldbeck, SOE Poster, 1999).

Participants: California Coastal Conservancy, S. F. Bay Conservation and Development Commission, San Francisco District, U.S. Army Corps of Engineers, and Hamilton Restoration Group.

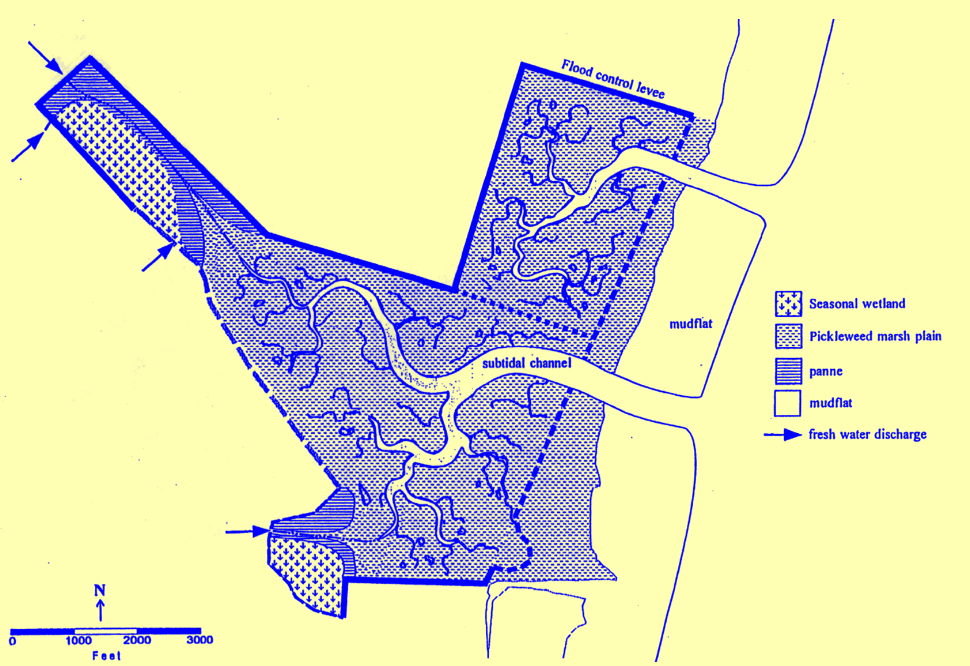
Design Consultants: Woodward-Clyde, Philip Williams & Associates, H.T. Harvey & Associates, and Eric Polson

➤ MORE INFO? tnevins@igc.org

Initial Conditions: Site Template Year 0



Evolution at Year 50



RARE PLANTS

Brenda Grewell, University of California, Davis

Emergent marsh plant communities are the visible defining elements of the San Francisco Estuary's tidal wetlands, and encompass a unique diversity of flora. Rare plants are important members of these communities and should be considered in conservation and restoration planning. Endangered tidal marsh plants include soft-haired birds beak (*Cordylanthus mollis ssp. mollis*), Suisun thistle (*Cirsium hydrophilum*) and Mason's lilaeopsis (*Lilaeopsis masonii*). Two other important marsh plants — California sea-blite (*Suaeda californica*) and California saltbush (*Atriplex californica*) — are now locally extinct. If we are to restore the integrity of our marshes, we should consider historic assemblages of plants including those which are locally extinct.

As many as 61 additional tidal-wetland-dependent species have been identified by the California Native Plant Society as plants of concern due to habitat fragmentation and degradation. Though no regulatory protection exists for many of these species, some of their habitat needs may be addressed in the U.S. Fish and Wildlife Service tidal marsh recovery plan.

Among the Estuary's rarest plants is the endangered Suisun thistle, a species occurring solely in Suisun Marsh. Only two populations of this thistle, which grows along small tidal creeks near the high marsh border, remain in existence today. Another rare species is the endangered soft-haired bird's beak. This annual plant survives the long, harsh season in the high marsh through parasitic connections to common marsh plants like saltgrass and pickleweed which contribute water and solutes needed for growth. Historically, soft-haired birds beak occurred from Antioch to the Petaluma marsh. Today it is restricted to ten populations between Central Suisun Marsh and Point Pinole. A third rarity is the state-listed Mason's lileaopsis — a diminutive member of the carrot family that has a fascinating ecology. This plant is specially adapted to life in the action zone, growing where waves erode and slump mud banks between the Delta and Mare Island. Tides transport floating propagules from this plant that have been dislodged by bank erosion,which may reestablish on other exposed banks. To maintain these metapopulation dynamics, restoration planners must consider providing extensive reaches of suitable habitat.

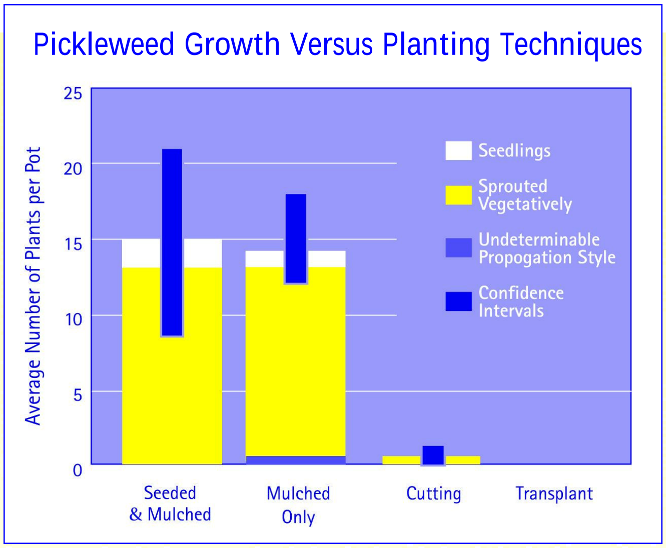
The Estuary's endangered tidal marsh flora have not always been rare. In most cases, these species are locally abundant but greatly reduced in range due to the diking, filling and fragmentation of tidal marshes throughout the Estuary. Such disturbances not only directly remove habitat and cut off natural linkages to fish,birds and other parts of the food web, but also limit seed dispersal and pollination processes. In addition,human alteration and management of the Estuary's hydrologic processes have impacted rare plants by reducing natural variation in their environment. Natural variability in climate, Delta outflow, watershed inputs and marine tides all affect the amount of flooding experienced by wetland plants.

NEW SCIENCE

Pickleweed Propagation Techniques

Research comparing various plant propagation and restoration treatments on the establishment of pickleweed (*Salicornia virginica*) in severely disturbed habitat showed substantial differences in effects. The research resulted from the U.S. Navy's decision to convert two parking lots to intertidal, brackish water marshes at the Weapons Support Facility Seal Beach Detachment Concord, as partial mitigation for a pier expansion project. The research documented the effects of two restoration treatments on the establishment of pickleweed: (1) enriching the soil with organic material (in this case, commercial compost), and (2) placing pickleweed material on the soil surface, i.e., mulching with pickleweed.

Results of a pilot greenhouse study showed substantial differences in the success of different propagation techniques tested (see chart). Transplants, cuttings, and seeding were rather ineffective at establishing recruitment, but pickleweed mulch placed on the soil surface sprouted readily. In the field, treatments and controls were applied to randomly selected plots in the former parking lots in fall 1998 and spring 1999. To prepare the lots, asphalt had been removed and the soil texture tested and enhanced with fine-textured material dredged from a nearby marina (soil under the asphalt was rocky and sandy, whereas soil in estuarine marshes is naturally more finely textured). Treatments then applied to the test sites were enriching the soil with compost (by rototilling), mulching with pickleweed, a partial control consisting of rototilling without adding compost, and a full control. Monitoring will continue seasonally, but visual inspections of the study plots suggest distinct treatment effects (Disney & Miles, SOE, 1999).



➤ MORE INFO?
Michele_Disney@usgs.gov

While salinity, hydrology and soils are often considered the determining factors in the establishment and zonation of tidal marsh plant communities, biological interactions also play a significant role. For example, several invasive species now challenge efforts to restore floristic diversity. Atlantic cordgrass is changing the primary functions and structure of tidal marshes as it traps sediment and raises marsh elevations (see p. 54). Meanwhile *lepedium latafolium*, the white flowered peppergrass, is actively displacing the endangered Suisun thistle and the rare Jepson's Delta tule pea. The peppergrass' close association with endangered species presents tremendous control challenges.

Despite such challenges, some of today's plant populations have been intact since the mid 1800s, before marshes were diked. Unlike birds and fish, most of these plants have not had the mobility to move to more suitable spots as habitat was lost or degraded. For this reason, rare plants are perhaps the best barometers of health in the Estuary and its habitats. Any work to restore the ecological integrity of the Bay's marshes must consider historic assemblages of plants, including species which are now locally extinct.

The most significant limiting factor to the successful sustainable restoration of the Estuary's historic floristic diversity is a basic lack of applied research yielding critical ecological data. If the historic landscape is to be our restoration guide, we should not miss the opportunity to learn more about these key species. Millions of dollars are spent researching fish and waterfowl each year, while in the past ten years there have only been a few small studies of rare plants. People's perspective on what are the biggest human impacts on the Estuary often comes directly from what's been studied most — namely fish. Tidal marsh plants are also directly affected by water management and should not have to grow gills to deserve attention.

REHAB ADVICE

- Conserve existing populations of rare plants.
- Give priority to restoration opportunities which link tidal marshes to alluvial soils, seeps, and drainages. The current tendency to create tidal marsh as indented pockets within levee systems separated from the Estuary's historic margins will not support historic floral diversity.
- Enhance the complex soil landscapes that support floristic diversity. Substrate and slope complexity are critical to restoration success. Many rare marsh plants and associates depend on the soil characteristics of peat-rich marsh soils formed from plant decomposition, or salinized and weathered upland soils where highly variable soil texture occurs. For this reason, other types of soils, such as imported mud or sandy material dredged from the Bay bottom, should only be used selectively in marsh restoration.
- Experiment with reintroducing rare or extinct plants. Be sure to distinguish between reintroductions of plants into habitats where they have been extirpated and translocation into potentially suitable habitats. Translocation has not been widely successful.
- Don't rely solely on today's remaining tidal marshes as perfect references to historic conditions. Plant communities and interactions with the environment, in particular, may be quite altered.
- Launch a long-term census of plant species. Link and expand census studies with research into the life history of rare plants and into the relationship between population size and extinction probability. Large scale environmental variation and dispersal rates may be more important determinants to extinction than plant population (Grewell, SOE, 1999).

➤ MORE INFO? bjgrewell@ucdavis.edu

NEW SCIENCE

Salt Marsh Dodder: Parasite or Helpmate?

Keystone species such as the salt marsh dodder may help us link population and ecosystem needs. This orange trailing vine is a parasite which is not capable of photosynthesis and thus remains completely dependent on its host plants for nutrients and water supply. Studies (Pennings & Callaway 1996) at Carpenteria salt marsh suggest that this plant can suppress competitive dominance, open up spaces and gaps for rare plants, and promote cycles of biodiversity. During the past two years, researchers from U.C. Davis experimentally removed salt marsh dodder from Bodega Marine Lab's salt marsh reserve. The effect on the initial and primary host plant was not surprising – growth and reproduction were significantly suppressed. The effect of this holoparasite removal on the rare hemiparasitic Point Reyes bird's beak was more surprising – bird's beak performed better when directly interacting with dodder. Researchers are now examining details of the population dynamics of these parasitic plant interactions and the full plant community response to dodder removal. Such preliminary results point to the need to consider rare plant recovery needs in a community context (Grewell, SOE, 1999).

MIGRATORY BIRDS

Gary Page, Point Reyes Bird Observatory

More than 80% of the historic tidal salt marshes and 40% of tidal flats in the San Francisco Bay Estuary have been lost to development or altered by diking. The tidal flats that are left, as well as the salt ponds which replaced marsh and mudflats, are important habitats for migratory and wintering shorebirds and waterfowl.

Shorebird Use of Tidal Flats Versus Salt Ponds*

Shorebird	Tidal flat		Salt ponds	
	Fall	Spring	Fall	Spring
Black-bellied plover	94	95	<1	<1
Marbled godwit	91	96	2	<1
Willet	90	87	2	3
small sandpipers	90	94	2	1
dowitchers	76	92	10	<1
American avocet	37	32	52	25
Snowy plover	16	40	69	51
Black-necked stilt	4	7	86	60
Red-necked phalarope	<1	<1	99	93

* Median percent of shorebirds on San Francisco Bay tidal flats and in salt ponds from preliminary analyses of PRBO data. Source: L. Stenzel and G. Page unpublished data.

Rehabilitation of historic tidal marshes is widely promoted as a means of increasing populations of species native to these wetlands. The great changes to the Estuary landscape, however, may preclude returning the ecosystem to historic conditions, nor may that be the most desirable goal. Restoration of tidal salt marshes is a developing science, and widespread success in restoring endangered species populations through such projects is not guaranteed.

What is clear is that man-made wetlands such as salt ponds now function as critical wintering and migration habitats for shorebirds, waterfowl and other waterbirds in the Pacific Flyway. Many species adapted to these new habitats over time, and those now favoring the salt ponds include ruddy ducks, avocets, stilts, snowy plovers and phalaropes. Current use of the Bay by phalaropes, for example, is likely much higher than it was historically due to creation of suitable new salt pond habitat here and lost habitat elsewhere. Tens of thousands of Wilson's and Red-necked phalaropes use the Bay's salt ponds in the fall. Likewise, 90% of the ruddy ducks visiting the Bay use the salt ponds. Many of the 20,000-25,000 wintering American avocets and black-necked stilts also forage heavily in the salt ponds. Conversion of these habitats to salt marshes will have negative consequences for many of these waterbirds.

REHAB ADVICE

- Acknowledge that we can't turn back the clock for San Francisco Bay.
- Remember — in the rush to restore tidal marshes — that we also need more mudflats for waterbirds.
- Preserve salt pond habitats. If the Bay's salt pond habitats are all converted to tidal marshes, many birds will have no place left to go (Page, SOE, 1999).

➤ MORE INFO? gpage@prbo.org

NEW SCIENCE

Diving Ducks Need Salt Ponds

Researchers examined midwinter waterfowl surveys from 1988 to 1999, before and after the end of salt production in the North Bay in 1992, to examine how waterbird use changes with conversion of salt ponds. Overall waterfowl numbers in the salt ponds fluctuated from 6,500 to 36,000 birds during the past decade with no significant trend. However, we found major changes in different foraging guilds. Dabbling ducks increased, while diving ducks decreased from 32,000 in 1989 to 3,600 in 1997. The species with the largest decline was the canvasback, which decreased 75% from 8,000 to less than 2,000 individuals. Change in waterbird numbers may be attributed to reduced water levels in the ponds, which favors dabbling ducks feeding in shallow surface water, rather than diving ducks feeding on benthic invertebrates in deeper water. Salt ponds provide diving birds with feeding areas, impoundments for roosting, and large, undisturbed areas of open water for safely taking flight.

Converting from one wetland habitat type to another may benefit some species at the expense of others. These recent analyses suggest that densities of diving birds in the winter and spring are four times greater in salt ponds compared with bayland wetlands. Thus, a far larger area of bayland wetlands may be required to compensate for the loss of salt ponds to maintain current diving bird populations. Future research efforts should be directed at developing suitable types of managed wetlands to replace values provided by salt pond systems and to maximize the value of the saline ponds that are developed from old salt ponds (Takekawa, Pers. Comm., 2000).

➤ MORE INFO? john_takekawa@usgs.gov

Tringa Habitat

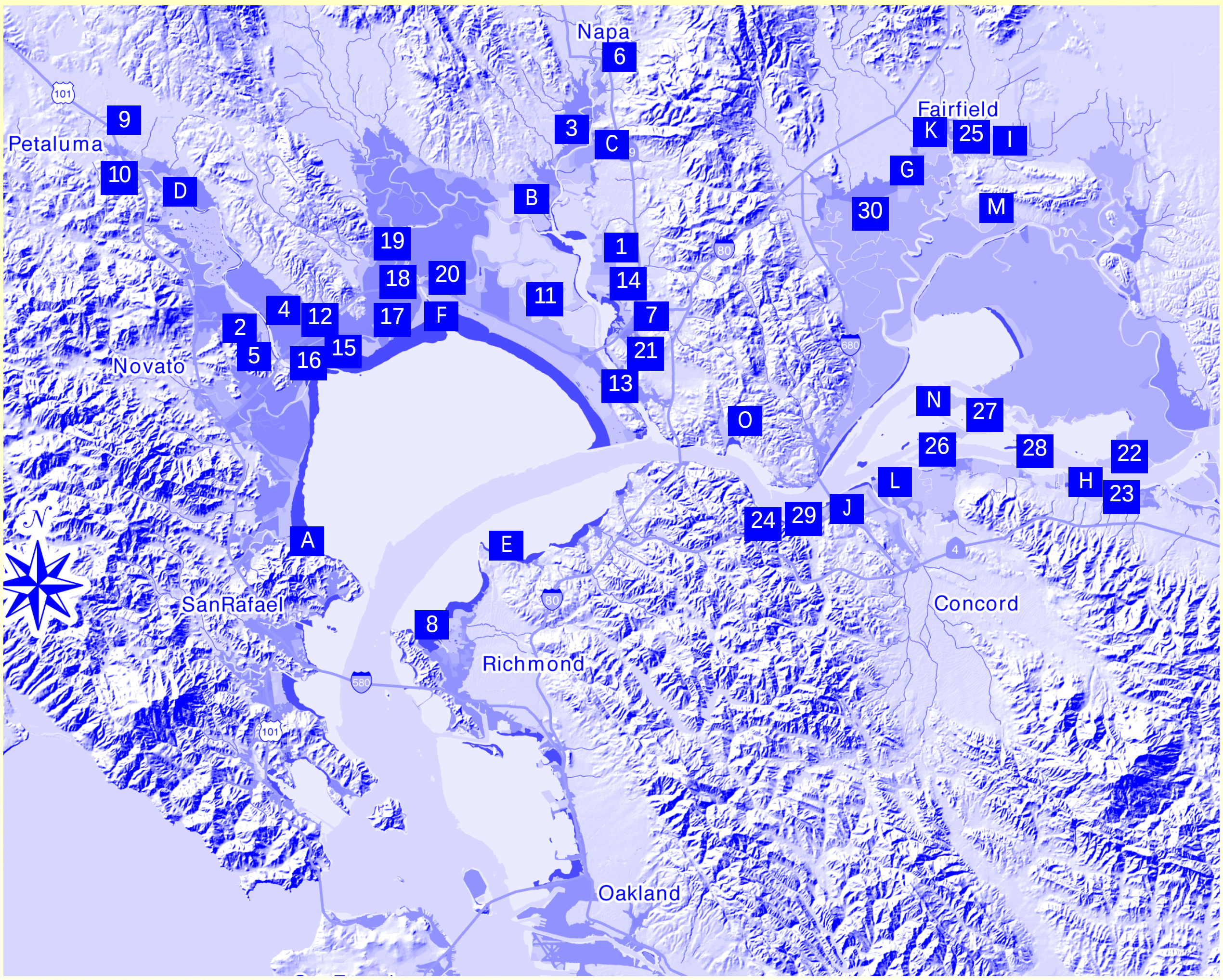
"Tringa" is the genus of greater and lesser yellowlegs and solitary sandpiper, three of eight species of shorebirds that need localities for rest, shelter and forage during migration periods and in the winter. Most of these species will not forage in tidal flats. Tringa habitat is fresh or lightly brackish water with grassy edges such as found in deltas, higher bayshore elevations, sewer ponds, creek mouths and some impounded wetlands, managed or natural. None of these species are agency listed but none are common here because their habitat here has been dwindling for decades. Most are detected here only during the fall migration with virtually none passing during the spring. Perhaps the manipulation of estuarine shores, along with the normal input of winter rains, eliminate enough Tringa habitat to alter migration routes. During the migratory periods, these species of birds greatly benefit when they can find suitable habitat in creek or river deltas or the drawn-down ponds of managed wetlands (Stallcup, SOE, 1999).

NEW SCIENCE

North Bay Rates and Patterns of Wetland Restoration

The Sacramento-San Joaquin Delta Breached-Levee Wetland Study (BREACH) is a CALFED-supported, interdisciplinary research effort comparing historically breached-levee wetlands to natural (unleveed) wetlands in order to better predict the feasibility, patterns and rates of restoration to natural ecological function. This map offers a preliminary inventory of all potential reference and naturally or intentionally breached-dike wetlands being considered by the BREACH program for a network of approximately 12 study sites in Suisun and San Pablo bays. The final study sites will be selected to represent likely points in trajectories between young (relatively unvegetated) and mature wetlands. Reference sites will be selected to characterize expected "restoration end-points," with priority given to sites that have existing data or are designated for long-term protection, research and management (e.g., new S.F. National Estuarine Research Reserve sites). Sites are likely to be distributed in "clusters" associated with two to three sub-estuary watersheds (e.g., Petaluma, Sonoma, Napa rivers, Suisun Slough). As of summer 2000, researchers had identified 30 breached-dike sites, and 15 reference sites, and gathered preliminary information about each site. The final site selection will occur in summer 2000 (Simenstad et al., *IEP Newsletter*). Suggestions for additional sites, or information on sites listed in this inventory, are encouraged and may be forwarded to Michelle Orr at mko@pwa-ltd.com.

➤ MORE INFO?
simenstd@u.washington.edu



Source: Base map from EcoAtlas, SFEI

Map Key

Reference Sites
A. China Camp
B. Coon Island / Fly Bay
C. Fagan Slough
D. Petaluma River Marshes
E. Point Pinole
F. Sonoma Creek (Mouth)
G. Boyton Slough
H. Concord Naval Weapons Station
I. Hill Slough
J. Peyton Marsh
K. Peytonia Slough
L. Point Edith
M. Rush Ranch
N. Ryer (West)
O. South Hampton Marsh

North Bay Breached Sites
1. American Canyon
2. Bahia Lagoon
3. Bull Island
4. Carl's Marsh
5. Greenpoint
6. JFK Memorial Park*
7. Meadows Drive*
8. Nevada-Shaped Parcel
9. Petaluma River 1*
10. Petaluma River 2*
11. Pond 2A
12. Port Sonoma Marina
13. Pritchett Marsh
14. Slaughterhouse Point
15. Sonoma Baylands Main Unit
16. Sonoma Baylands Pilot Unit
17. Tolay Creek, Dickson Lagoon
18. Tolay Creek 1
19. Tolay Creek 2*
20. West End Duck Club*
21. White Slough

Suisun Bay Breached Sites
22. Chipps Island (West)
23. Concord Naval Weapons Station
24. Martinez Waterfront Marsh
25. Peytonia Slough Pond
26. Roe
27. Ryer (East)
28. Seal Island
29. Shell Oil Marsh North*
30. Sunrise Island

* Additional information is needed to confirm inclusion of these sites in the inventory.

INTRODUCED SPECIES

Tom Dudley, University of California, Berkeley

Non-indigenous species of plants and animals, introduced from other regions into California ecosystems in which they did not evolve through human activities, are now major threats to biodiversity and ecosystem function throughout the Sacramento-San Joaquin watershed, including many areas dedicated to the protection of native species and natural ecosystems. The majority of protected species in California are associated with wetlands and riparian areas, so interference by invaders can have serious implications for their survival and restoration of the estuarine ecosystem. Based on surveys of natural area managers throughout California, it is conservatively estimated that there are 142 non-indigenous plants and animals considered management problems in aquatic and riparian ecosystems of the state, 90% of which are present within our watershed (many others are present, but either too common for control or not sufficiently problematic to warrant concern).

Of these, 69 species are considered serious invasive pests, species known to directly threaten sensitive native species or to alter ecosystem characteristics. Besides interfering with declining native species through competition, predation and habitat degradation, these invaders also cause substantial economic damage, including increased fire risk, flood debris and erosion problems with giant reed (*Arundo*), or disruption of water delivery systems and of fisheries by Asian clams (*Corbiculafluminea*), water hyacinth (*Eichhornia crassipes*), and mitten crabs (*Eriocheir sinensis*).

High elevation headwater streams tend to be less prone to non-indigenous species impacts, presumably because physiological stress reduces the number of species that can tolerate the winter. Lower elevation headwater streams are invaded by numerous plant species, particularly those which form dense stands that choke out native species along stream margins, including Himalayan blackberry (*Rubusdiscolor*), English ivy (*Hedera helix*), Cape ivy (*Delairea* odorata), and periwinkle (*Vinca major*). In a few locations, purple loosestrife (*Lythrumsalicaria*), which has been so problematic in the eastern states, is present and is the subject of control programs. In other sites, saltcedar (esp. *Tamarixparviflora* in our region) has come to dominate streambanks and alter riparian dynamics throughout the West. In addition to bullfrogs and non-native trout, and a whole host of other exotic fish, crayfish also threaten natural ecosystems through their voracious, omnivorous behavior, and there are fears that the Chinese mitten crab may soon enter many smaller streams as it has done in Sonoma Creek, or invade sensitive vernal pools during high water periods.

NEW SCIENCE

Smooth Cordgrass Spread & Control

The proliferation of invasive smooth cordgrass (*Spartina alterniflora*) — and its hybridization with California cordgrass (*Spartina foliosa*) — could grossly alter the character of San Francisco Bay and now threatens numerous newly-restored tidal marshes and mudflats. This East Coast native was purposefully introduced to south San Francisco Bay about 25 years ago to promote wetland restoration, and has since spread by further plantings and seed dispersal by tides. Previous work suggested that smooth cordgrass was competitively superior to native California cordgrass, and that the two species hybridized. In 1997, researchers began a study to determine the spread of *S. alterniflora* and *S. foliosa* x *alterniflora* hybrids in California using DNA markers diagnostic for each species to detect the parental species and nine categories of hybrids. All hybrid categories exist in the Bay, implying several generations of crossbreeding. Researchers primarily found hybrids near South Bay sites of deliberate introduction of *S. alterniflora*. However, a few hybrid plants were discovered north of the Golden Gate. Where smooth cordgrass was deliberately planted, the marsh was composed of roughly equal numbers of smooth cordgrass and hybrid individuals, while the native species was virtually absent. Marshes colonized by water dispersed seed contained the full gamut of plant types with intermediate-type hybrids predominating. This proliferation of possibly highly fit hybrids could result in local extinction of native species. What is more, smooth cordgrass has the ability to grow both higher in the marsh and lower down the intertidal gradient than the native cordgrass, and thus to modify the estuary ecosystem to the detriment of native species and human uses of the Bay.

Smooth Cordgrass Proliferation

The genetic patterns observed by researchers provide general guidelines to curbing the spread of smooth cordgrass and its hybrids. Control efforts should focus on the complete extirpation of populations that contain few pure native plants since these populations export large numbers of hybrid seed. In addition, smooth cordgrass and hybrids could be selectively removed from native marshes that have not been heavily invaded. Other tactics, aimed at preventing new invasions, are to temporarily curtail opening new areas of unvegetated mud to the Bay, particularly in infested areas, since the populations of seedlings that establish are likely to contain huge numbers of hybrids. Also, uninvaded marshes should be regularly monitored to prevent invasion and only pure native cordgrass from uninvaded marshes should be used for restoration projects (Ayres, SOE Poster, 1999).

➤ MORE INFO? drayres@ucdavis.edu

Downstream in lower gradient floodplains, additional thicket-forming species have become abundant in the watershed, especially giant reed, which is increasingly the subject of local control efforts. Natural hydrological processes are thwarted, as these thickets promote excess sedimentation in some sites, while resulting in erosion and channel cutting in others because of their shallow root systems.

Invasive Species in Wetlands & Riparian Zones

	California	Watershed	Serious Invaders
Plants	72	68	36
Animals	70	61	33

As floodplains merge into Delta riparian habitat, many of these plants are still present, along with additional pests like perennial pepperweed (*Lepidium latifolium*) and Russian thistle (*Salsola soda*). Also in the Delta, and in Bay habitats downstream,are whole hosts of invasive animals and fully aquatic plants. Oftentimes these non-indigenous species interact to promote each other's establishment, such as exotic plants altering soil to favor other exotic plants, or providing habitat for introduced predators and yielding a more insidious problem than would have been presented by a single species alone.

Given the current interest in restoration of many areas toward their former natural condition, and in creation of new habitat as mitigation for environmental losses elsewhere, the role of non-indigenous species in these sites becomes critical. However, many invasive species are particularly well-adapted to establishment in areas that have been mechanically disturbed, as would be the case following habitat restoration. For example, smooth cordgrass (*Spartina alterniflora*) from the Atlantic coast has invaded numerous sites in the south Bay where tidal mudflat restoration or creation has been undertaken, such that it could become advisable to clear the slate and start over.

Likewise, in brackish/freshwater marsh projects, such as Warm Springs Marsh and Sonoma Baylands, perennial pepperweed is invading newly-cleared substrates from levees and spoils sites nearby. Stone Lakes Wildlife Refuge is restored agricultural land, but experiences severe water hyacinth infestation requiring control each year. In smaller streams nearly every riparian restoration project we've observed in the Bay Area (e.g. Strawberry Creek, Wildcat Creek, Sausal Creek, Presidio streams, and many others) is inundated by the many invasive plants mentioned earlier, by encroachment from adjacent landscapes or waterflow; or by inadequate removal of invasive plants during the restoration work itself.

REHAB ADVICE

- Be prepared. Restoration sites are particularly susceptible to invasions. Take careful account of the potential for invasion as watershed-wide projects are planned and undertaken.
- Remember that the following may promote invasions: hydrological changes/flow regulation; channel and soil disturbance;loss of native riparian habitat;and nutrient inputs.
- Coordinate restoration plans with surrounding land uses and possible invasive species impacts.
- Put some effort into making sure you get the vegetation you want at your restoration site (build it and they will come).
- Maintain constant vigilance over restoration sites. Support monitoring programs that will provide early detection of invasive species and follow-up control,so as to avoid the greater expense of secondary restoration of these habitats at a later date (Dudley, SOE, 1999).

➤ MORE INFO?
tdudley@socrates.berkeley.edu

PROJECT IN ACTION

Common Reed Control

Control of the common reed *(Phragmites australis)*, an aggressive invasive plant that grows in moderately to highly saline environments, is a central element in an effort by Grizzly Island's TuleRed Duck Club to restore a portion of its property disturbed by a drainage ditch and to enhance adjacent wetlands. The project aims to lessen the impact of non-native vegetation and promote the growth of native wetland plants that in turn provide habitat for endangered species, as well as the familiar ducks and geese that visit the Delta. To begin the project in 1995, biologists surveyed and examined the levees, interior lands and the bay shoreline and determined historic water levels, flows and tidal flooding, as well as associated percent cover and frequency of plant species. Management practices then undertaken include disking, mowing and applying herbicides, which reduced nonnative plants, then seeding and allowing the area to be recolonized by the marshland species ducks prefer. Subsequent site monitoring shows that aggressive management can control the common reed. However, because of the plant's invasive nature, treated areas will soon revert to dense stands of common reed without continued management (Redpath, SOE Poster, 1999).

➤ MORE INFO? gredpath@ttsfo.com

CHEMICAL CONTAMINATION

IMPLICATIONS FOR REHABILITATION

Sam Luoma,U.S. Geological Survey

Though chemical contamination of the San Francisco Bay-Delta has diminished since passage of the Clean Water Act in 1970,a range of biological indicators suggest contaminant stress continues. These include sediment toxicity, tissue residues of contaminants, biochemical and histological indicators of stress in resident organisms, reproductive anomalies in resident organisms, simplified communities and unstable populations. Solving the remaining problems will not be simple. On-going study of contamination issues is crucial to the sustainable rehabilitation of the Bay-Delta ecosystem.

The status of contamination is influenced by several factors:modern inputs from human activities; historic human activities like mining;and the physical,chemical and biological characteristics of the system. Other important influences include changes in freshwater inflows and water movement patterns, patterns of sediment deposition and erosion,the interchange of water and sediments between all segments of the Bay-Delta,phytoplankton blooms and food web characteristics.

Recent scientific studies point to a number of contamination issues that will be important as we move into the rehabilitation phase of estuarine management in the next century:

Contaminant Exposure Links with Bay Physical Characteristics

- Studies of historic lead contamination (Ritson et al,1999) show that contaminants from single point sources can spread throughout the interconnected reaches of the Bay-Delta,probably because the Bay is a shallow and well-mixed system.
- Hotspots of polychlorinated biphenyls (PCBs) have been identified (Davis et al,SOE Poster, 1999). Despite bans on production decades ago, PCB concentrations in the Bay overall are not declining as rapidly as in many areas of the world. The ability of the Bay to spread contaminants from point sources over large areas may be one cause of continuing regional-scale PCB contamination in water, sediments and birds. Studies of PCB redistribution are badly needed and new approaches to remediation of highly dynamic Bay sediments may be necessary.

NEW SCIENCE

Metal Dynamics in Intertidal Wetlands

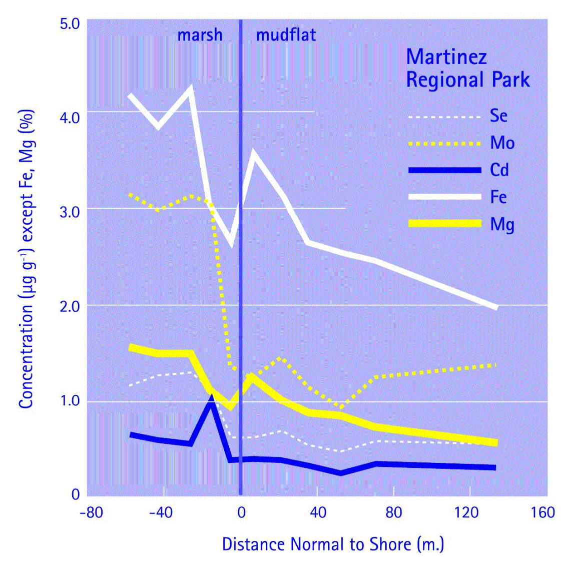
Multidisciplinary studies of selenium and heavy metal cycling in intertidal marshes in the Carquinez Strait have yielded estimates of the relative importance of processes by which trace elements are imported into the system. Sampling, fractionation, and analysis of sediments from the surface depth of 20 cm, both in marsh and mudflat environments, show selenium to be predominantly (>90%) chemically reduced, i.e. relatively immobile and insoluble in elemental and organic forms. Similarly, after deposition, particle-bound selenium does not become further reduced in shallow sediments.

Concentrations of all trace elements were found to increase from mudflat to marsh, apparently due to the differences in the size of the particles which settle out in each of these environments. Selenium concentrations ranged from around 0.5 parts per million (ppm) in mudflat sediments to around 1 ppm in marsh plain sediments. Significantly higher selenium and metal concentrations were associated with the finer fractions. The similar spatial distribution of selenium and trace metal concentrations in the shallow sediments supports the idea of suspended particulate matter deposition as the primary flux of selenium and trace metals to the intertidal marsh.

In-situ measurements of sediment deposition have generated estimates of sediment-associated trace element depositional rates. These results show a seasonal pattern of trace element concentration, inversely related to the flow of water in the Carquinez Strait, with concentrations lowest in the winter and highest in the summer and fall. Patterns of trace element concentrations on sediment traps agree semi-quantitatively with element distribution in the shallow marsh sediments. The results of these and related studies suggest that monitoring selenium concentrations on suspended particulate matter at the sediment-water interface may provide the data most representative of conditions to which benthic organisms are exposed (Zawislanski et al, SOE Poster, 1999).

➤ MORE INFO?
PTZawislanski@lbl.gov

Trace Elements in Martinez Regional Park Wetlands



Trace element concentrations in the top 20 cm of intertidal sediment. Concentrations of all elements, including selenium, increase inland, from the mudflat to the marsh.

- The Bay's food web is contaminated with methyl mercury (SFBRWQCB, 1995). Advisories exist prohibiting human consumption of some larger, longer-lived fish,a typical sign of mercury contamination. Recent research shows that hydraulic mining debris is an important source of mercury in bay sediments (Hornberger et al, 1999). Most of the debris was buried beneath sediments that were deposited between 1890 and 1950. However, these deposits have increasingly been uncovered since the 1950s, probably as a result of the effects of dam construction (dams trap sediments higher up in the watershed (Jaffe et al,SOE Poster, 1999; Bouse et al, SOE Poster, 1999). Hydraulic mining debris deposits may be a major source of contamination to the food web.

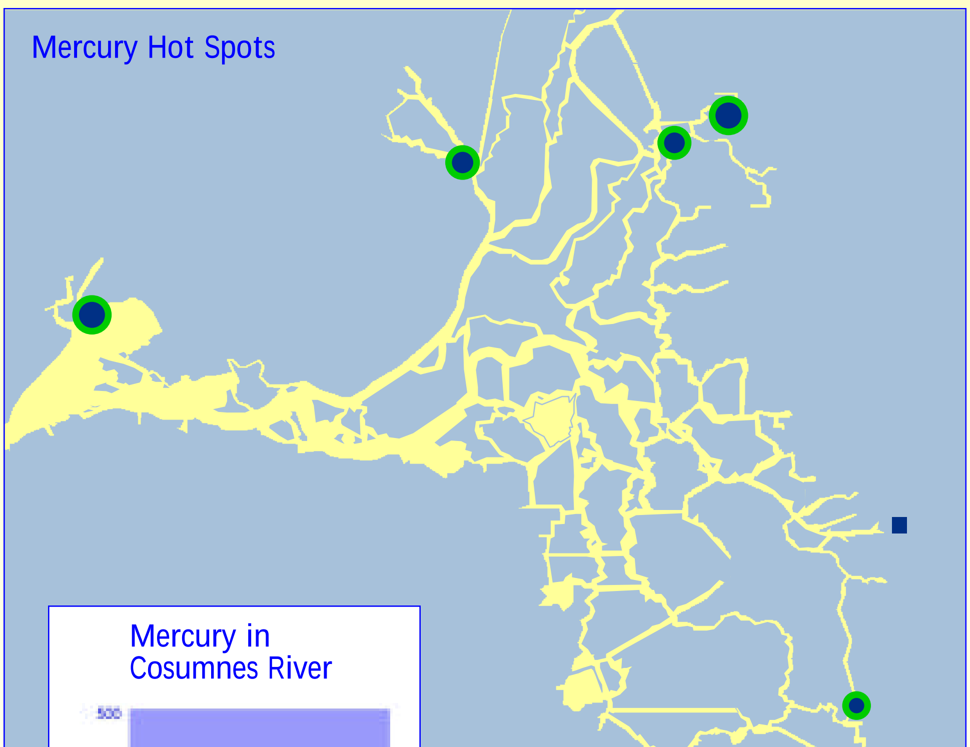
NEW SCIENCE

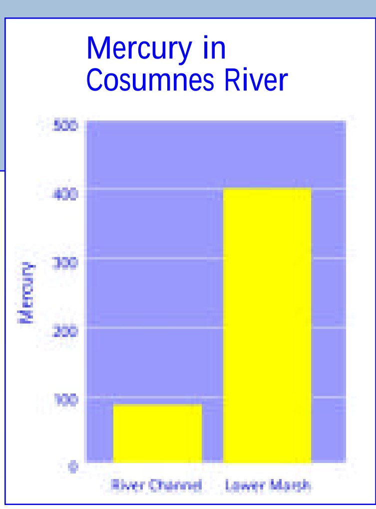
Methyl Mercury Consequences of Bay-Delta Restoration

Preliminary results of an ongoing three year study examining which key parameters most strongly affect mercury methylation in the Delta suggest that wetland restoration projects may vary significantly in localized mercury bioaccumulation, as a function of their location within the Bay-Delta.

It has been hypothesized that the restoration of former wetlands (previously diked for agricultural production) by re-flooding, together with the addition of thousands of acres of new tidal wetlands to the overall system, may result in a net increase in the production of methyl mercury — the most-dangerous and bioavailable form of this metal — in the Bay and Delta. Though the habitat benefits of such restoration work are clear, a significant net increase in fish mercury levels and associated human health and wildlife exposures would be detrimental.

This CALFED-funded study quantifies relative mercury bioaccumulation by key, site specific indicator organisms at numerous Delta sites spanning a range of physical, chemical and biological gradients that may be important to mercury methylation.





These gradients include salinity, sediment mercury load and speciation, age of tract since re-flooding, Coast Range mercury mining inputs versus Sierra Nevada refined quicksilver inputs, potential ameliorative effects of selenium from San Joaquin (Kesterson) inputs versus Sacramento River inputs, etc. Monitoring is focused on organisms with high site fidelity — crayfish, small and juvenile fish, clams, etc. — as opposed to highly mobile adult fish.

Additionally, the relative potential of sediments from various tracts for mercury methylation has been quantified in laboratory experiments.

Findings from Fall 1998 & Spring/Summer 1999 from 29 diverse sites indicate similar levels of mercury bioaccumulation across much of the central Delta, with significantly elevated levels linked primarily to proximity to certain regions. Apparent source-related regions include the Cosumnes River (un-dammed Sierra Nevada quicksilver inputs), portions of the North Delta Wetlands (Coast Range mercury mine inputs), and possibly the San Joaquin River above Stockton (additional Sierra Nevada inputs). An apparent hot spot in the Suisun Slough region may be linked to the salinity gradient/entrapment zone. In related laboratory experiments, researchers have demonstrated a dramatic enhancement of mercury methylation potential in organic-rich Bay-Delta wetland habitats, as compared to sand flats and typical channels.

All wetland conversion will likely enhance localized mercury methylation to some degree. But these findings suggest that future wetland restoration strategies least likely to increase net mercury methylation rates and associated biological uptake may include strategic placement of restoration sites away from known elevated mercury source areas and otherwise high methylation regions of the system, as determined by research. The project is currently processing a large set of consistent samples collected in Fall 1999 from over 70 diverse sites. These should provide greatly enhanced resolution of Bay-Delta mercury bioaccumulation trends. In addition, ongoing laboratory experiments will further refine understanding of the regional and microhabitat factors influencing mercury methylation (Slotton et al, SOE Poster, 1999 & Pers. Comm., 2000).

➤ MORE INFO?
dgslotton@ucdavis.edu

Changing Inputs

- If marsh restoration proceeds at locations contaminated with mercury-laden hydraulic mining debris, mercury contamination in the Bay food web could worsen.
- Selenium occurs in elevated concentrations in sturgeon and some migratory birds in the Bay (Urquhart and Regalado, 1991), and threatens reproduction in these species. The processes that caused the historic selenium problem were identified in the 1980s (Cutter 1989; Johns 1989; Luoma et al 1992). However the issues surrounding selenium contamination are changing. Proposals exist to discharge selenium from saline soils of the Western San Joaquin Valley directly into the Bay. As a result of changes in water management, San Joaquin River inflows to the Bay may be on the rise. Selenium concentrations in bivalves are presently higher than they were in the late 1980s, despite reductions in local oil refinery inputs of the element. The cause of higher bivalve contamination is not fully known.
- Sporadic large inputs of modern pesticides from rivers and streams in the Bay are linked to periods of high river inflows. Inputs were once thought to be confined to short-term pulses, but new data show increased concentrations of some pesticides can extend for months in Suisun Bay (Kuivila, SOE Poster, 1999).

Contaminant Mixtures

- Analytic methods are only available for determination of 16% of the pesticides used by California agriculture (Kuivila et al, SOE Poster, 1999). Nevertheless, 50% of the water samples collected from the San Joaquin River have seven or more pesticides that are detectable. Similarly in the Bay, the simultaneous presence of a wide variety of pesticides is an important potential problem. Toxicity of pesticide-contaminated waters is apparently widespread in rivers. But effects on resident species in the Bay and its watershed are not known, and the effects of mixtures of pesticides have not been adequately addressed.

Surprises on the Horizon

- Contamination with combustion related hydrocarbons (e.g. polyaromatic hydro-carbons — PAHs) appears to be widespread in the Bay. PAH uptake and induction of biochemical detoxification systems were related to reproductive problems in starry flounder fifteen years ago (Spies 1998). But little further study has occurred, even though areas being proposed for restoration and dredging could contain significant PAH deposits.
- Historically silver and copper contamination at a hotspot in the South Bay caused reproductive failure in local resident bivalves. As a result of

PROJECT IN ACTION

Sediment Remediation at United Heckathorn

The United Heckathorn site, located in San Francisco Bay's Richmond Harbor, was used to formulate pesticides between 1947 and 1966. Soils at the site and sediment in Richmond harbor were contaminated with chlorinated pesticides, primarily DDT, as a result of shipping and formulating activities. DDT is a persistent and bioaccumulative toxic substance which was banned by the U.S. Environmental Protection Agency (EPA) in 1972. EPA listed United Heckathorn as a Federal Superfund site after California State Mussel Watch monitoring data showed that the mussels in Richmond Harbor had the highest DDT concentrations in the state. EPA responses began in 1990-1993, with the removal of roughly 3,000 tons of pesticide residues and contaminated shoreline soils. Studies of contaminated harbor sediments in 1994 found DDT as high as 630 parts per million (PPM) dry weight at the head of the Lauritzen Channel. Cleanup occurred in 1996-1997, and involved dredging of 112,660 tons of sediment containing approximately three tons of DDT. The sediment was then dewatered on site, and shipped by rail to permitted landfills. In April 1997, the dredged channel was capped with 0.5-1.5 feet of clean sand.

Long-term monitoring to assess the effectiveness of clean up showed that chlorinated pesticide concentrations in resident mussel tissue were reduced by 61-70% from pre-remediation levels by the second year. These reductions occurred not only at the site, but also throughout Richmond Harbor. Similar reductions occurred in dieldrin and PCB levels. However total DDT in the Lauritzen Channel water and in the semi-enclosed adjacent waterways still exceeded the remediation goal of 0.59 nanograms per liter (Lincoff et al, SOE Poster, 1999). These and results of other monitoring (Anderson, SOE Poster, 1999) suggest that dredging of the channel sediments did not sufficiently reduce risk of exposure of chemicals of concern to resident benthic biota. Lauritzen Channel sediments continue to be contaminated by concentrations of DDT, dieldrin, and in some cases PAHs, that are sufficient to account for amphipod mortality in laboratory experiments. Such results demonstrate the importance of chemical and biological monitoring at San Francisco Estuary sites proposed for sediment remediation, and suggest that multiple indicators that consider both water and sediment exposure pathways be used in future post-remediation monitoring studies.

➤ MORE INFO? Lincoff.Andy@epa-mail.epa.gov or anderson@ucdavis.edu

Total DDT in Resident Mussels (ppb, wet wt.)

STATION	1991-92 (pre-dredging)	1998 (1st year)	1999 (2nd year)
Lauritzen Channel (center)	2900	4504	606
Lauritzen Channel (mouth)	-	1222	176
Santa Fe Channel	350	256	75.6
Richmond Inner Harbor	40	127	29.7

improvements in advanced waste treatment and source control, contamination has receded, and reproduction in the clams has returned to successful levels (Hornberger et al,SOE Poster, 1999b). Evidence from the North Bay also suggests that cadmium and silver may chemically interfere with reproduction in resident fauna (Brown,SOE Poster, 1999). Effects of metals on reproduction of animals is indicated by both studies, but has not been adequately researched.

- Primary sources of copper have changed since 1990. Questions about ecological effects of copper and nickel on phytoplankton in the South Bay remain unanswered. New South Bay issues, such as bridge construction and airport runway modifications, could influence future effects of silver, copper, mercury, cadmium and PAHs that may be buried in bay sediments.

REHAB ADVICE

- Obtain sediment cores to test for chemical contamination from areas proposed for restoration,dredging or any increase in hydraulic residence times. Hydraulic mining debris, mercury, selenium,PCBs, metals and PAHs are of concern. Where contaminants are present, study remediation methods and undertake remediation when possible before restoration begins. Work to better understand if and where disturbance of sediments, or other activities accompanying habitat enhancements, mobilize contaminants in bioavailable forms. Precedent exists for increasing contamination problems by flooding lands (i.e. for restoration) in the absence of contaminant remediation measures.
- Consider improvements to San Joaquin River water quality as part of any proposal to increase its inflows into the Bay. Some water management proposals aimed at helping improve Delta farming, environmental and habitat conditions may result in greater quantities of poor quality San Joaquin River water entering the Bay than under current conditions. Selenium and pesticide contamination are of particular concern.
- Remember that restoration of some species may be inhibited unless pesticide inflows are better controlled, judging from the widespread indications of pesticide toxicity in the watershed. Researchers and environmental managers should work to better understand the effects of mixtures of pesticides, and the combination of pesticide exposure with other Bay-Delta stresses, in order to identify appropriate control procedures and justify their expense.
- Identify and clean-up hotspots of contamination,and identify areas where hotspots in sediments may be uncovered. Once on the surface, contaminated sediments may be distributed throughout the Bay (Luoma,SOE, 1999).

➤ MORE INFO? snluoma@usgs.gov

PROJECT IN ACTION

Guidelines for Ecosystem-Friendly Cities & Farms

The way cities and farms grow, operate and use water has an enormous impact on the health of the Bay-Delta ecosystem, and on opportunities for ecosystem restoration. Though there was not enough room in this report to cover the myriad actions that urban residents, land use planners and farmers may take to promote restoration, the following resources provide excellent action lists.

- *Improving Our Bay-Delta Estuary Through Local Plans and Programs: A Guidebook for City and County Governments*, ABAG (Including a checklist of policy options for protecting water quality, wetlands and wildlife).

➤ MORE INFO? (510)622-2465

- *Blueprint for a Sustainable Bay Area, Urban Ecology* (Ideas for homes, neighborhoods, cities and the region, with case studies.)

➤ MORE INFO? (510)251-6330

- *Agricultural Solutions: Improving Water Quality in California Through Water Conservation and Pesticide Reduction*, Natural Resources Defense Council

➤ MORE INFO? (415)777-0220

- *Farming for Wildlife, Voluntary Practices for Attracting Wildlife to Your Farm*, California Department of Fish & Game, (Specifics on beneficial farming practices aimed at the farming community.)

➤ MORE INFO? (916)653-1768

- *Local Wetland Protection Handbook*, Save the Bay (Ways for local governments, agencies, stakeholder organizations and individual citizens to protect and restore wetlands).

➤ MORE INFO? (510)452-9261

PERSPECTIVE

Fate of the Estuary

Luna Leopold,
formerly of U.S. Geological Survey & University of California, Berkeley

The restoration, and thus the fate of this unique geographic feature, the Estuary, is influenced by, and ultimately dependent on, three things: science, the application of knowledge derived from science, and the operating administrative-political forces.

If there is validity to this simplified characterization of a complex subject, then it follows that we should pay attention to these principal forces, and not be satisfied with lengthy discussions of peripheral matters that are of small importance to the larger picture.

The kinds of questions that will no doubt arise include the following: Where in the watershed are the principal sources of sediment and contaminants and what processes provide them? What is the effect of tidal marshes on the sediment budget and on the tidal prism of the whole Bay? How do marshes act as filters of sediment and contaminants, and what is the relation of plant architecture in the marsh to the filtering effect?

Exploring such questions will take time and effort and all proposed shortcuts must be viewed with skepticism.

"The best science and its most useful application may be negated by failure of the administrative-political establishment to draw some limits on the exposure of the ecosystem to the overpowering destructive pressure....of our national pursuit of unlimited growth."

To make the best use of science, it would be well to develop a carefully chosen list of the major scientific questions that stand unanswered. These might be divided into different magnitudes of scale such as regional problems, subregional problems and local ones.

In what direction will the scientific capability be deployed? It might be argued that more is known about the Bay itself than about the relation of the Bay to its watersheds. We can expect an increasing pressure to develop new knowledge about watershed functions, but it must be realized that the watersheds involve more diverse problems and different circumstances than occur in the Bay's waters and on its shores. This complexity poses a conundrum in that the administrative-political arms want answers that come quickly and with assurance. These expectations are antithetical to the operation of good science which is usually time-consuming and provides a tentative and far from assured answer. Most will require field observations and cannot be solved even with the most sophisticated computer models.

With regard to the application of science, we now have an organized and practical program of monitoring trace elements in bay waters. However, we are far from sure how to use this information to influence the production of, or ameliorate the effects of, undesirable trace elements.

The U.S. Geological Survey has made great contributions to knowledge of the Bay in their studies of circulation of bay waters, of primary production, of benthic cores, to name just a few subjects.

On wetlands that border the Bay, we have just completed a study of the goals indicating what habitats in what quantities seem desirable for the health and welfare of the ecosystem. This is a real accomplishment in the application of scientific knowledge to practical problems. This project has involved hundreds of experienced people all volunteering their help. The next step, monitoring change and hopefully progress, is still ahead.

Another valuable application of science to practical problems is the development of the S.F. Estuary Institute's EcoAtlas. It shows in amazing detail on maps the ecotypes in the Bay region as of 1800 AD and again in the present year. Knowledge of original conditions is essential for estimating the possible endpoints of restoration attempts.

These examples of application of scientific knowledge remind us that science gives us results that are often hesitant, partial and sometimes useless. But these qualifications of the expectations of science should not be considered too discouraging, in view of the administrative-political milieu in which bay restoration exists. There is a large variety of federal, state, and private organizations, each having particular interests and backing, as well as dedicated public groups devoted to preserving and improving the Bay. All are under the crushing force emanating from the national pursuit of unlimited growth.

This relentless striving for expansion applies increasing stress to all natural systems and is felt in the Estuary in a multitude of ways. The best science and its most useful application may be negated by failure of the administrative-political establishment to draw some limits on the exposure of the ecosystem to overpowering destructive pressure. Mitigation of destructive action, even when successful, is ultimately an admission of defeat.

We must persuade the American public that it is in their interest to slow, if not stem, the forces that tend to destroy our ecological base. It is my opinion that science, and the application of science, will not accomplish the aims that will be elucidated in the present conference. Rather we must give highest priority to altering those administrative-political forces that contribute to degradation of the Estuary (Leopold, SOE, 1999).

MEASURING AND MODELING TOOLS

NUMERICAL MODELS: IMPLICATIONS FOR RESTORATION

Stephen Monismith, Stanford University

Numerical models are a major tool for assessing the environmental impacts of engineering works in the Bay-Delta system,and for trying to predict what changes in circulation might accompany physical changes in the Estuary due to restoration or re-plumbing projects.

Several types of model are currently being used for this purpose, each suited to addressing different classes of questions and each with significant limitations:

- Statistical models like the "G" model or Flow-Salinity relations are best suited to address changes in salinity due to changes in bulk parameters like reservoir releases or Delta pumping. They cannot be used to say anything about transport of organisms or biogeochemistry of the system.
- Properly calibrated one-dimensional channel network models like DSM2 can represent effects on salinity and on organism transport of some forms of system modification, most notably the operations of in-channel gates, or the addition of narrow channels to the existing plumbing. However, they cannot predict the behavior of large open areas such as might be created by breaching levees.
- Two and three dimensional circulation models build in more physics and thus have greater predictive capabilities. Because they make few assumptions, state-of-the-art three dimensional models can be used to predict the effects of a wide variety of engineering actions on circulation patterns and transport rates. However, these models require accurate bathymetry and run slowly on currently available platforms. They also work best when high quality data are available for their calibration and validation.

Unlike physical models of the Bay, numerical circulation models can be used in conjunction with models of phytoplankton growth,nutrient dynamics, or even with models of the behavior of individual organisms like zooplankton or bivalve larvae, to make inferences about how changes in the physical system might affect ecosystem processes in the Bay.

In terms of long-term utility, it may be time to develop a three dimensional circulation model, named (as a strawman) "Bay Model 2000," covering all of the Bay Delta system as well as the adjoining coastal ocean. This model could be viewed as a 21st century replacement for the physical Bay model in Sausalito. It would take advantage of modern parallel computational technology to operate at a useful speed, i.e.,much faster than real time. In practical terms this means that it would likely be a numerical model written to run efficiently on a large (and fast) network of desktop computers. Like models used to do weather prediction,it would maintain accuracy by assimilating in real time the many available data streams such as those coming from sensors located throughout the system and operated by the Department of Water Resources, the U.S. Bureau of Reclamation and the National Oceanic and Atmospheric Administration. Finally, unlike the existing physical model,this computational Bay model could be used (for example) to drive models of phytoplankton dynamics that would be used to assess the risk of harmful algal blooms arising as a consequence of the creation of new shallow water areas in the Delta.

NEW SCIENCE

Floodplain Modeling

A preliminary model combining hydrology and population dynamics suggests that flooding can significantly impact splittail viability in the Delta. It is now recognized that floodplain processes should be restored to rehabilitate the Bay Delta ecosystem including native fish inhabitants (CalFed ERPP Vol. I, 1999). There is still debate, however, over the quantity and location of habitat to be restored. Models are useful tools for establishing objectives, selecting among alternatives, determining appropriate indicators and associated "performance metrics" and interpreting monitoring information to assess progress.

Researchers developed a floodplain modeling tool to investigate possible effects of floodplain habitat restoration in the Sacramento delta ecosystem. Conceptual and mathematical models were created to illustrate a method that is both scientifically rigorous and relevant. The modeling approach combines a hydrologic model with population modeling techniques to investigate the possible effects of expanding the area of flooding and timing of inundation on splittail population viability in the Yolo Bypass. Splittail live for 5 - 7 years, spawn on flooded vegetation and are highly fecund, which is believed to allow the population to rebound during wet years when the bypasses are flooded (Caywood 1974, Meng and Moyle 1995). The preliminary model suggests that changes in egg mortality (affected by floodplain inundation) can significantly impact recruitment rates and overall population viability.

Formulation of a useful model for investigating possible population responses to various management scenarios requires a description of the dominant sources of variability at various stages of the splittail life cycle. This modeling project, which is still in its infancy, has largely demonstrated the utility of such an approach and pointed to the importance of acquiring data on splittail-habitat relationships (Pawley, SOE Poster, 1999).

➤ MORE INFO? pawley@bay.org

There is the question of how numerical models might be used to assess the impacts of restoration of the Bay-Delta system. It is possible to assess, with reasonable confidence, salinity effects of policies and facilities, as well as changes in entrainment of passive particles into the pumps. It may be possible to generate "ballpark" estimates of changes in primary production,as well as changes in rates of sediment deposition,erosion and transport. Understanding of both these important basic ecosystem processes is limited, however, and both are currently the subject of CALFED-sponsored research by the U.S. Geological Survey. Thus, in reality the jury must be considered out on our ability to model them. Lastly, essentially nothing is known about exchanges between the Bay and the ocean, and how ocean conditions might affect populations of organisms that live in both for parts of their life cycles, and little is understood about how primary production is linked to higher trophic levels. For example, even the large perturbation to the system that one might infer the Asian clam, *Potamocorbula amurensis*, has wrought is the subject of much ongoing debate, and shows how far we are from being able to understand how changes to the overall system might ultimately play out (Monismith, SOE, 1999).

➤ MORE INFO? monismit@cive.stanford.edu

PROJECT IN ACTION

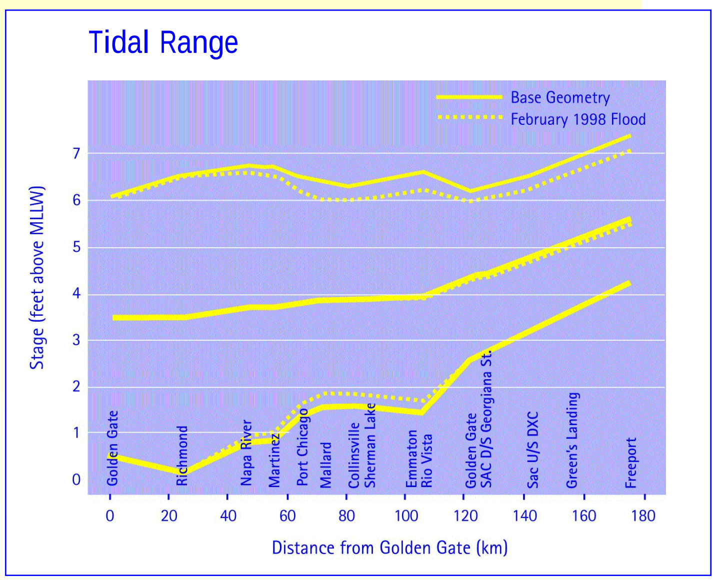
Modeling Salinity Impacts of Suisun Levee Breaches

Modeling research examining the assumption that 1998 breaches in Suisun Marsh levees would lead to higher Bay and Delta salinity suggests that the actual response is more complex. In February 1998, the tidal prism of Suisun Bay was expanded by 40% when spring tides, low pressure, storm winds and El Niño ocean conditions combined to breach or overtop levees in more than 60 locations in Suisun Marsh. To evaluate the potential impacts of not repairing the levees, researchers from the Department of Water Resources conducted a hydrodynamics and salinity modeling analysis — simulating historical hydrology, facilities configurations, and water project operations between October 1991 and September 1994. This approach provides enough time for the salinity response to propagate through the system and affords the opportunity to examine impacts for three dry years and one wet year.

Researchers also examined the sensitivity of salinity mixing to breach size, location and extent of inundated area. Two breach configurations were simulated: first, the February 1998 flood as eleven breaches of 100-feet-wide by 10 feet below MLLW (mean low lower water); and second, as expanded breaches comprising 10-40% of the exterior levee perimeter. Two additional four year simulations explored a hypothetical levee failure on the San Joaquin River side of Sherman Island.

Findings suggest that the salinity response of this type of event depends on the complex balance between friction, bathymetry, tidal prism, and tidal range/tidal excursion. General observations are: 1) salinity is increased in western Suisun Bay but reduced in the north and south Delta. The magnitude of the change, and the location of the cross-over between salinity increase and reduction, is a function of the configuration and location of the levee breaches; 2) the tidal range is reduced up to one half foot along the axis of the Estuary and the average water level is reduced in the Delta (see chart); 3) over half the inundated area volume is exchanged through the levee breach at each tide. CALFED responded to this research by setting up a Suisun Marsh levee investigation team to determine costs and benefits of including these levees in their overall levee rehabilitation program, and to identify beneficial linkages with CALFED's other programs. Subsequent focused modeling analysis by the team suggests that carefully designed restoration and levee breach projects in the marsh could provide opportunities for win-win ecosystem and water quality improvements (Enright et al, SOE Poster, 1999).

➤ MORE INFO? cenright@water.ca.gov



28-day average tidal range between Golden Gate and Sacramento via Sacramento River.

CHOOSING THE BEST MAP
AVAILABILITY, ACCURACY AND ACCOUNTABILITY

Zoltan Der et al, San Francisco Estuary Institute

The use of computerized Geographic Information Systems (GIS) is rapidly increasing among government agencies and environmental interest groups as they work to document, protect and restore the landscapes and resources of the Bay Area. GIS — maps produced from layers of digitally based geographic information — is evolving from "maps of maps" to Internet search engines that provide access to spatial data and their sources through interactive maps on-line.

But the increased use and improvements in GIS do not necessarily mean that maps have gotten better. In many cases, GIS seems to conceal the errors of existing maps, or it creates new maps with their own errors. Many maps that exist as part of GIS are not available to people who do not have the same GIS. Digital maps can also imply an undue amount of map certainty or accuracy. For example, the zoom feature of a GIS or any other software for viewing digital maps can make possible a closer examination of boundaries and detail than is supported by the original maps or their sources of information. Overlays of maps in a GIS can suggest more or less spatial correspondence between features than really exists. And there are choices in digital maps for many places. All of this raises some practical questions:which map is best, how are the choices compared, and how should the errors of a digital map be displayed?

The San Francisco Estuary Institute was asked by the Marin County Community Development Agency to help address these questions with regard to existing maps of the historical uplands margin of the San Francisco Estuary in Marin County. The Agency intends to use a map of this boundary for long-range land use planning. The Institute and the Agency worked with partners in and out of government to identify four maps to be compared. All of these maps were being used in one form or another by agencies, consultants and the concerned public. At issue was the fact that each map showed a different boundary, and that the Agency lacked sufficient rationale to choose between the maps.

On behalf of the Agency, the Institute developed a detailed understanding of the original purposes and methods of production and reproduction of the various maps, based upon their written documentation and interviews with their authors. The Institute then made a detailed study of all possible spatial errors for each map. A flow chart was constructed to show how errors might inter-relate, and the total spatial error for each map was quantified. Finally a composite map was made showing the comparable boundary lines, in the context of their probable errors. The Institute deferred to the Agency for any decisions about the relative values of the maps.

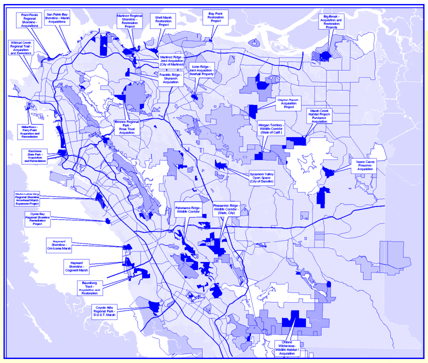
The study provided the following conclusions and recommendations. Firstly, no map is useful unless it is readily available. All the maps have met their original, intended purposes. Cartographic errors that result from misinterpretations of the landscape, either in the field or the office, tend to be much greater than errors incurred during map production or reproduction. The needed accuracy of a map depends on its intended use;a general land use plan may not require the most accurate map. Accountability may be more important than accuracy, especially when choosing among maps that are equally inaccurate, in the context of their intended use. And finally, line thickness or buffers should be used in a GIS to display the expected error of important boundaries (Der et al,SOE Poster, 1999).

➤ MORE INFO? zoltan@sfei.org

PROJECT IN ACTION

Acquisition, Enhancement and Restoration Projects in East Bay Parks

The GIS map opposite highlights some of the East Bay Regional Park District's parks, open space and trail facilities in Alameda and Contra Costa Counties, and shows lands the District is helping to enhance or preserve through environmental partnerships. The District currently operates 55 parks and open space areas, manages more than 91,000 acres of land, and is leading or participating in more than 15 enhancement and restoration projects along the San Francisco Bay shoreline. A large percentage of these projects have focused on restoration and management of tidal marshlands and other aquatic habitats to benefit such species as the salt marsh harvest mouse, Delta smelt, California clapper rail, least tern and soft bird's beak. Other shoreline projects focus on the restoration of coastal prairie, riparian areas and seasonal wetland habitats to benefit other species, including Santa Cruz tarplant, snowy plover and burrowing owl. The district is also making a substantial commitment of resources to manage and protect these restored habitats from a variety of natural and human-related threats, including control of introduced predators and non-native vegetation (eastern cordgrass and artichoke thistle, for example), and the remediation of soil and groundwater contaminants (Olson, SOE Poster, 1999).

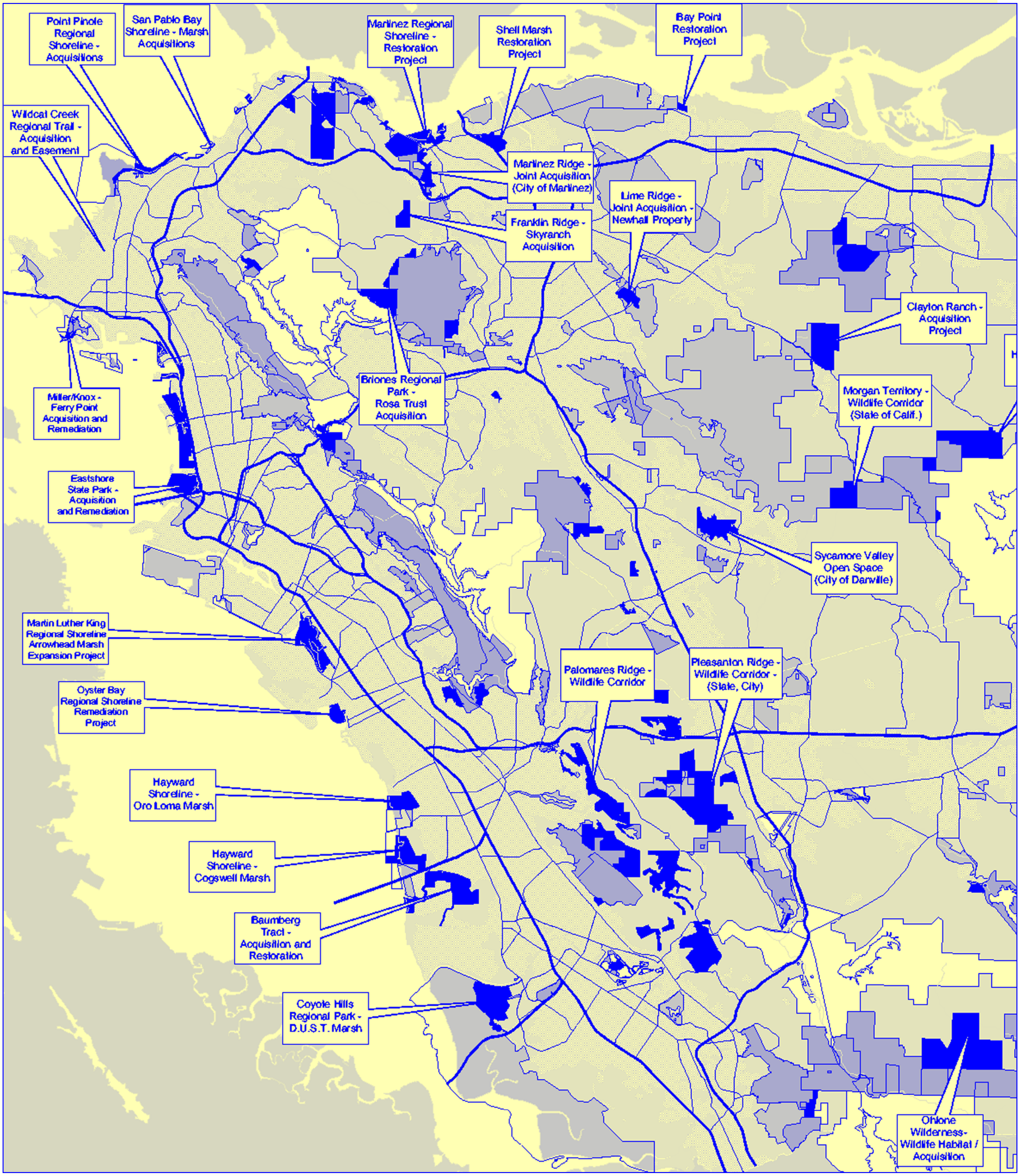


PROJECT IN ACTION

East Bay Parks continued

Measure AA acquisitions
EBRPD Parklands
Water Districts
Other Public Lands
Partnership Acquisitions
Shoreline Acquisition/ Restoration/ Enhancement Projects
Proposed Shoreline Acquisitions

County Line
Freeways
Major Roads
Shoreline / Streams



PERFORMANCE CRITERIA
FOR IMPLEMENTING A NO NET LOSS OF WETLANDS POLICY

Andree Breaux et al,
S.F. Bay Regional Water Quality Control Board

In California, the state regulates all discharges to its waters and wetlands under the Porter Cologne Act, and the California Wetlands Conservation Policy requires that there be no net loss of wetland acres or values. At the federal level, wetland policy in the United States is also guided by the goal of no net loss of wetland habitat, and is enforced primarily through the permitting requirements instituted under the Clean Water Act. Under these regulations, a permit applicant is required to provide compensatory mitigation when wetland loss cannot be avoided or minimized. Such projects generally take the form either of the restoration of previous wetland sites or of the creation of artificial wetlands on upland sites. The progress of wetland development is usually measured by performance criteria which are standards set on a project-by-project basis to assess functional changes or ecosystem development in compensatory wetland mitigation projects. Determining the success of these projects can sometimes be difficult since wetlands develop like gardens, with some elements planned but others not. So, while we are ensuring that there is no net loss of acreage, it is difficult to ensure no net loss of functions. This research reviewed some of the typical performance criteria used to track ecosystem changes in wetland compensatory mitigation projects proposed or permitted between 1988 and 1995 in the San Francisco Bay region.

The three tables shown on these pages (pp. 67-69) summarize research findings. Between 1988-1995, as a result of 116 compensatory mitigation projects in the Bay region, 548 acres of wetlands were lost and 619 gained (plus 653 in indirect gains). Among the projects, over 50 different parameters were measured to assess wetland development and function, and project "success." The most measured feature of compensatory mitigation sites was vegetation, with hydrology a distant second. Wildlife was measured but usually only as a qualitative assessment of "evidence of use." Target wildlife frequently consisted of endangered or threatened species. The least cited criteria were water quality, soils and invertebrates.

The following organizes the results by the most-cited performance criteria within each of the three predominant wetland project types.

Riparian (36 of 116 projects)

- The target vegetation for such projects consisted predominantly of tree species, such as the coast live oak (*Quercus agrifolia*), California buckeye (*Aesculus californica*), red willow (*Salix laevigata*), valley oak (*Quercus lobata*), sycamore (Plantus racemosa), white alder (*Alnus rhombifolia*), cottonwood (*Populus fremontii*), and coffeeberry (*Rhamus californica*).
- Percent cover was cited as a performance criteria in 26 of the riparian projects.
- Percent survival was listed as a performance standard in 22 of these projects. Within these 22, 9 set a goal of 75% survival after 5 years; 4 set a goal of 80%; and 2 set a goal of 90%. The remaining 7 projects using percent survival as a criterion had a variety of targets, such as a comparison of the planted site to a reference site after 10 years; a 50% survival of planted vegetation after 3 years; and 75% after 2 years.

PROJECT IN ACTION
Adaptive Management on San Diego Bay

At San Diego Bay's Sweetwater Marsh National Wildlife Refuge, the inclusion of a strong research component in a mitigation program made it possible to document outcomes of habitat creation efforts and to explain many of the causes. As in San Francisco Bay, the coastal wetlands of San Diego Bay support multiple endangered species, three of which were jeopardized by new construction projects (a highway and flood control channel). Because endangered species were involved, damages to habitat had to be mitigated, and strict compliance criteria had to be met.

Studies of habitat created for the three species began five years after the first mitigation site was excavated in 1984. Research included the development of assessment tools to determine compliance with mitigation requirements and sustainability; remote sensing to quantify the area of different habitats; spatial monitoring of endangered plant populations using global positioning and GIS; and experiments to test alternative soil amendments.

The assessment program documented compliance for two species (California least tern and salt marsh birds beak —a plant) but not for the third (light-footed clapper rail). For the tern, the mitigation requirement was to construct channels that would support the tern's favorite food (fish). Researchers compared fish samples in the new channels with those in natural channels and found that compliance was achieved in year three.

For the bird's beak, mitigation required re-establishment of a previously extirpated population. Seeds were sown for three years and the resulting population complied with standards in 1995. But the population shrank in 1996, a drought year. Follow-up research suggested that more attention be paid to factors limiting seed production (such as nitrogen and pollinators) and to control of exotic annual grasses. Bird's beak is a hemiparasitic plant that taps into a host plant for water and nutrients, but the exotic hosts are annual (unlike the perennial natives) and they die before the birds beak achieves maturity.

For the light-footed clapper rail, mitigation required three things: crabs for food, a high-tide refuge, and nesting habitat. Researchers found that habitat had serious short-comings, namely coarse soil, low nutrient supplies, short vegetation, scale

Perennial Tidal (27 of 116 projects)

Perennial tidal systems include all tidal or estuarine wetland projects that target saline, brackish,or more rarely, freshwater vegetation systems, and which are influenced by the tides.

- The target vegetation of this type of wetland included predominantly salt marsh vegetation, since most of the wetland sites were saline or brackish.
- Twelve of the reports used percent cover as a criteria,with figures set between 70% and 90% after five or six years.
- Six reported no performance criteria at all.

Perennial Non-Tidal (3 of 116 projects)

Perennial non-tidal includes freshwater systems. This category is noticeably small because most of what is generally classified as freshwater emergent has been placed under freshwater seasonal.

- Perennial non-tidal fresh systems generally target *Carex sp.,Scirpus sp., Juncus sp*.,and often are designed to include trees.
- Two of the three cited 75% cover in five years.
- The third cited 75% survival after five years.

Seasonal Wetlands (33 of 116 projects)

Seasonal wetlands are defined as wetlands that have seasonally saturated soils or are periodically flooded. They include all ranges of salinity, and they embrace both diked and non-diked areas.

- While vegetation was the single most-cited criteria in the other categories of wetlands, hydrology was the most cited criteria for this category. Criteria were diverse: One project stated a requirement for ponding through May, but set no quantitative objectives;others required documentation of the saturation and ponding at several predetermined points at the beginning and end of the autumn rains;one project set a performance criterion as soil saturation (within the root zone) for at least 30 days of the growing season in at least three of five monitoring years; another project set two hydrology targets — one for a channel system with the seasonal wetland requiring inundation of 21 consecutive days (8% of the growing season),and the second for a seasonal pond area requiring inundation of at least 13 consecutive days (5% of the growing season).
- Percent cover was also used often in seasonal wetlands. For those that did not set cover as a comparison to reference sites, the range was between 70% and 90%,with most projects fixing on 75% or 80%.
- Five of the 33 projects contained no information on performance criteria.

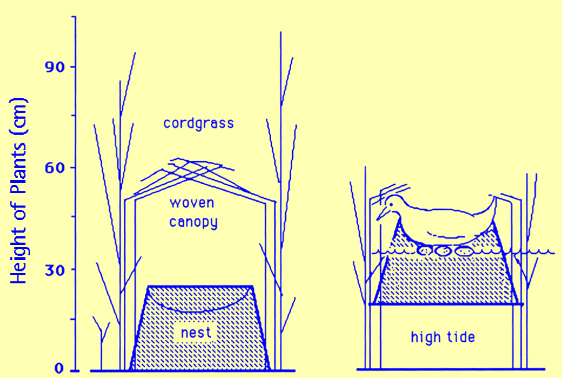
In conclusion,the selection of adequate performance criteria is crucial if wetland regulators are to

WETLAND ACRES LOST AND GAINED

In the 116 Bay Area Projects Examined For 1988-1995

Wetland Losses:	548 acres
Direct Wetland Gains:	364 acres created
	118 acres restored
	137 aces of upland buffers planted
Total Direct Gains:	619 acres
Indirect Wetland Gains:	599 acres enhanced
Preserved Wetlands:	28 acres preserved
Miscellaneous Gains:	26 acres
Total Indirect Gains:	653 acres

Clapper Rail Nesting Needs



insect outbreaks, and inadequate nesting habitat for rails. Rails never nested in the marshes designed for their use. The main problem turned out to be that the cordgrass was too short to be woven into a protective nest canopy (see diagram).

Further assessment suggested that the substrate was too sandy to supply enough nitrogen for the plants to grow tall, and that the plants were too short to support ladybird beetle predators of the scale insect that was damaging the cordgrass. A ten-year data set predicted that soil development would take at least 40 years to match conditions at the nearby reference site. Because the height of the cordgrass was actually declining, it was unlikely that cordgrass would ever reach height standards.

Collegial interactions among all the members of the adaptive management team (the mitigators, regulators and scientists) and trust in the scientific findings were instrumental in gaining concurrence that the mitigation project met criteria for two of the endangered species but not the third. The team agreed that an alternative penalty should be set for damages to the light-footed clapper rail.

Experience at San Diego Bay has broad application. The work pinpoints five ecosystem components that should not be ignored in restoration: anthropod predators, plant canopy structure, soil structure, soil nutrients, and site landscape interactions (Zedler, SOE, 1999).

➤ MORE INFO?
jbzedler@facstaff.wisc.edu

PARAMETERS MEASURED

In 116 Bay Area Compensatory Mitigation Projects 1988-1995

	Total Number of Projects	% of Projects Measuring Parameter
VEGETATION		
Percent Cover	84	72%
Percent Survival	59	51%
Species Diversity/Richness	41	35%
Vigor	32	28%
Species Dominance	31	27%
Height	30	26%
Natural Regeneration/Recruitment	6	5%
Basal Area	5	4%
Productivity	5	4%
Canopy Stratification	4	3%
Root Development	4	3%
Density	3	2%
HYDROLOGY		
Surface Water Levels	26	22%
Channel Geometry and Stability	23	20%
Depth and Duration of Ponding	22	19%
Inundation	18	15%
Sedimentation Rates	16	14%
Tidal Monitoring	13	11%
Salinity as Conservative Tracer	9	8%
Groundwater	8	7%
Elevation	7	6%
Velocity/Flow Rates	6	5%
Pore Water	5	4%
Soil Saturation	3	3%
WATER QUALITY		
Temperature	8	7%
Conductivity	5	4%
Dissolved Oxygen	5	4%
pH	4	3%
Turbidity	2	2%
Nitrogen	2	2%
Phosphorus	2	2%
Coliforms	2	2%
Biological Oxygen Demand	2	2%
Heavy Metals	2	2%
Organics	2	2%
Chlorophyll a	1	0.1%
Ammonia	1	0.1%
Total Organic Carbon	1	0.1%
Total Suspended Sediment	1	0.1%
Sulfide	0	0%
Pesticides	0	0%

	Total Number of Projects	% of Projects Measuring Parameter
SOILS		
Grain size	4	3%
Nutrients	2	2%
pH	2	2%
Salinity	2	2%
Soil colors related to saturation/oxidized root channels	2	2%
Texture	1	0.1%
Porosity	1	0.1%
Moisture	1	0.1%
Conductivity	1	0.1%
INVERTEBRATES		
Benthic Organisms	4	3%
Algae	2	2%
Phytoplankton	1	0.1%
WILDLIFE		
Evidence of Use	44	38%
Target Habitat	14	12%
Population County	14	12%
Diversity/Richness	12	10%
Egg Count	2	2%
Behavior	1	0.1%

be required to assess overall wetland losses and gains, as well as the success of individual compensatory wetland mitigation projects. What is adequate will depend in part on site specific features, but should also follow some general framework for what is measured, and how and when.

This research begins the process of standardization by simply finding out what has been measured as performance criteria in compensatory wetland mitigation projects between 1988 and 1995. For tidal wetlands the results conform to the literature indicating that percent cover is the most frequently used parameter to determine project success or failure. In general, 75% cover appears to be the conventional and adequate measure of success for tidal wetlands. In regard to riparian wetlands, the use of vegetation as a criteria requires further agreement as to whether percent cover or percent survival is the best criteria to use. For seasonal wetlands, the determination still remains as to what the length of the growing season should be and how long ponding should continue to accommodate biological species.

Future functional assessments should include detailed baseline studies at both the compensatory wetland mitigation sites and the potential development sites to determine where and how potential functional losses could occur. Monitoring requirements should be based on the size of the compensatory wetland mitigation project, with larger sites requiring more detailed assessments for a longer period to minimize wetland functional losses (Breaux et al, SOE Poster, 1999)

➤ MORE INFO? ab@rb2.swrcb.ca.gov

TYPICAL WETLAND BENEFICIAL USES OR FUNCTIONS

Groundwater Discharge
Warm Freshwater Habitat
Groundwater Recharge
Estuarine Habitat
Baseflow Augmentation
Freshwater Replenishment
Flood Storage Desynchronization
Marine Habitat
Nutrient Processing
Fish Migration Habitat
Sediment/Toxics Retention
Fish Spawning Habitat
Education/Research
Wildlife Habitat
Uniqueness/Heritage
Preservation of Rare, Endangered Species Habitat
Economics
Navigation
Ocean-commercial and Sport Fishing
Aesthetics
Areas of Biological Significance
Shellfish Harvesting
Plant Communities
Agricultural Supply
Cold Freshwater Habitat
Industrial Service Supply
Contact Recreation
Non-contact Recreation

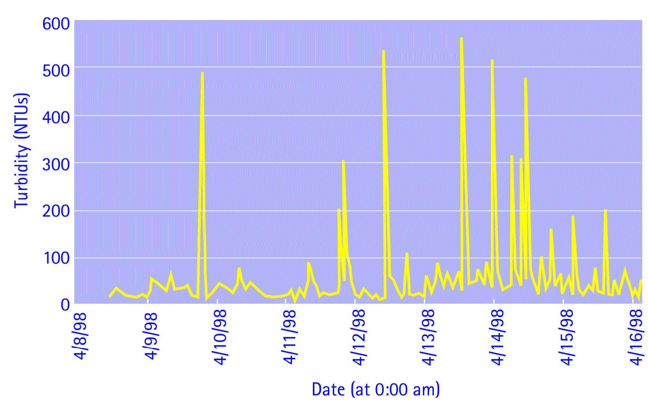
NEW SCIENCE

Monitoring Dredging Effects on Eelgrass

A new approach for monitoring the effects of dredging events on eelgrass beds — monitoring required by local agencies — was used in the Richmond Harbor Navigation Improvements Project in San Francisco Bay, California. The approach was based on the relationship between light availability, as indicated by photosynthetically active radiation (PAR), and the estimated hours of irradiance-saturated photosynthesis (Hsat) required to maintain whole plant carbon balance and growth. Daily average Hsat values were calculated from PAR measurements and compared to threshold Hsat values required for maintaining eelgrass health. The technique involved the use of modified Hydrolab instruments that measured light irradiance (PAR), turbidity, depth, salinity and temperature. The instruments were deployed directly above existing eelgrass beds before, during and after each dredging episode. Monitoring activities spanned a total period of nine months, allowing measurements to be taken under highly variable weather conditions. Results showed that the dredging events caused no measurable effect to local eelgrass populations as indicated by hours of photosynthetic saturation (Hsat). Average daily Hsat values reached a minimum of 6.6 hours, during dry-weather dredging events, but were generally above the recommended threshold of 3 to 5 hours for San Francisco Bay eelgrass populations. Although dredging events affected light regime and turbidity, their effect was short lasting. The data also showed that other factors, such as boat activity and winter storms, significantly affected turbidity levels, but were also relatively short-lived (Langis et al, SOE Poster, 1999).

➤ MORE INFO? rlangis@ch2m.com

Turbidity Spikes
Due to Tugboat and Vessel Activity at Station 3



CALFED INDICATORS OF ECOLOGICAL INTEGRITY

CALFED Ecosystem Restoration Program Indicators Work Group

The CALFED Ecosystem Restoration Program (ERP) proposes to restore and/or rehabilitate various ecological processes, habitats, species and biotic assemblages in the Bay-Delta estuary and its watersheds. Ecological indicators have an essential role in any ecosystem restoration program employing a science-based adaptive management strategy. Ecological indicators are measurable ecosystem attributes or surrogates that provide information on environmental conditions, trends, and their significance; they help assess program performance. The ERP will likely employ three general interrelated types of ecological indicators: indicators of ecological integrity or health; management oriented indicators of program/project performance and success; and, public oriented indicators of program performance.

The ERP Ecological Indicators Group, composed of environmental scientists from CALFED agencies and stakeholder organizations, developed indicators of ecological integrity or health for the ERP. The group devised a process or framework for indicator development, and adopted an ecological hierarchical approach for subdividing the CALFED program area and the developing indicators. This hierarchy has landscape, ecosystem, habitat, and species/ecological process levels. The group focused on the ecosystem and landscape levels. The ecosystems are: greater San Francisco Bay, the Sacramento/San Joaquin Delta, Central Valley alluvial river-floodplain, and mountain river-riparian. Key ecosystem level attributes or characteristics for each of these ecosystems were described. These attributes are arrayed in the following categories: hydrologic and hydrodynamic, geomorphic, natural habitat, biological community, and energetics and nutrient dynamics. Additional steps in the process include delineating human stressors on

Potential Landscape Level Indicators of Ecological Integrity

Natural Habitat

Attribute: Landscape level habitat patterns or mosaic (e.g. spatial extent, habitat diversity, configuration).

Landscape level indices or measures of diversity (number) and spatial extent (proportional representation) of selected habitats. Relative to a reference.

Landscape level indices or measures of habitat configuration.

Number of selected habitat types not represented by at least two areas of sufficient size and ecological functions to support native species.

Attribute: Biological and physical (ecological process) connectivity at landscape level.

Net change in the number of anthoropogenic instream barriers (e.g. physical temperature, hydrodynamic related) to migratory aquatic species (e.g. anadromous fish) movement across the landscape.

Net change in the number of anthropogenic barriers to water flow, sediment transport and supply, and nutrient transport across the landscape.

Indices or measures of connectivity for organisms and ecological processes among patches of the same habitat type (for major habitat types, e.g. riparian); and/or clusters of multi-habitat complexes.

Water and Sediment Quality

Attribute: Water and sediment quality parameters within natural ranges; toxic contaminants at levels that do not adversely impact native organisms.

General Water Quality Indicator: Number of water quality standard violations per year at selected sites across the landscape.

Toxic Contaminants Indicators:

- Load Reduction: Change in amount of selected contaminants entering the system from anthropogenic sources.
- Landscape level contaminant index for selected toxics based on a scoring matrix for concentrations in water, sediment and biota.

NEW SCIENCE

13 Essential Ecological Indicators

Every professional who has researched, monitored or regulated portions of the San Francisco Bay-Delta River system has been asked the question, "How healthy is this ecosystem?" In order to provide an easily understandable, yet scientifically valid answer to that question, Environmental Defense convened a panel of nationally recognized scientists to develop a set of Essential Ecological Indicators.

The panel used a methodological framework to capture the complex array of structural, functional and compositional elements of ecological integrity. The panel chose not to include stressors, which require a separate set of indicators. The panel divided ecosystem attributes and processes in the estuarine system of the San Francisco Bay-Delta into six categories (see below). Panel members then selected indicators for each category, in part by referring to the more detailed and comprehensive set of indicators proposed as part of the CALFED program (see above), and to earlier work done by the Bay Institute and the University of California at Berkeley.

The panel agreed on the following 13 Essential Ecological Indicators.

HABITAT

1. Habitat Types

This indicator will measure the number of habitat types, characteristic of the pre-1850 system, that are still represented by a certain number of viable patches. It will encompass the diversity of habitat types (e.g., wetlands, forests, mudflats) essential for the ecological integrity and biodiversity of the system. A minimum number of viable representatives with protected status are needed to hedge against the possible failure of management and restoration activities. The indicator will only reflect natural patches of habitat (i.e., not manipulated habitats such as rice fields or duck clubs) that are larger than a minimum viable size, connected to migratory corridors or other habitat patches, in some sort of protected status, and that conform to the historical location of that habitat type.

2. Habitat Proportions

This indicator will measure the degree to which the extent of the major habitat the ecosystem,developing conceptual ecological models, and establishing indicator selection criteria. These tools, plus program objectives and additional scientific information, were used to develop a broad suite of potential ecosystem level indicators of ecological integrity for each ecosystem. The indicators are organized into the same categories as the attributes (see opposite).

Proposed ecosystem level indicators for greater San Francisco Bay, for example, include X2 (position of the 2 parts per thousand isohaline in the Estuary) and other salinity patterns;spatial extent and distribution of patches of all natural habitat types; toxic contaminant concentrations in sediment, selected biota,and water; population trends of selected endangered species;non-native invasive species:measures of new invasions and distribution,spatial extent, and abundance of selected species;and marsh primary productivity. The group also developed potential landscape level indicators of ecological integrity.

CALFED's proposed indicators are "work in progress" in that they need additional review and refinement by experts in appropriate disciplines (Morrison,SOE Poster, 1999).

➤ MORE INFO? morrison@usfws.gov?

Potential Landscape Level Indicators of Ecological Integrity

Hydrologic

Attribute: Freshwater flow patterns (timing, magnitude, and distribution) through the system.

Central Valley River Indices
(Eight Rivers, Sacramento Valley, San Joaquin Valley)

Net Delta Outflow Index

Estuarine salinity patterns (perhaps X2 and/or mean annual salinity at a series of fixed points).

Ratio of system runoff to water flowing through the system at various locations.

Biological Communities

Attribute: Spatial distribution of species.

Number of selected species exhibiting range extensions. Index of percent range extension for selected species.

Attribute: Anadromous Fishes. Broad distribution of self sustaining populations.

Distribution, movement, and/or population trends. Selected species and/or cumulative index.

Attribute : Birds. Distribution and diversity of self-sustaining populations of migratory bird species.

Population trends (e.g. abundance, reproductive success), distribution and movement. Selected species and/or cumulative index.

Attribute: Listed and other At-Risk Species (defined by CALFED Conservation Strategy).

Number of "listed" species and other at-risk species (relative to reference). The following are subsets of the above that could also serve as indicators:
- number of delisted species
- number of new (including candidate species) listings
- number of extirpated species

Index of population trends (% increase/decrease) of select listed species.

Attribute: Nonnative Invasive (Exotic) Species

Measures of new invasions/introductions

Spatial extent and distribution of selected exotic species.

Number of exotic species eradicated or no net increase in spatial extent or distribution.

types reflects their pre-1850 distribution and proportions. Such a measure is important because the restoration of habitats out of proportion to their historical distribution may produce bottlenecks in the reproduction, rearing, and growth of species (such as salmon) that use many different kinds of habitat. The indicator will only reflect natural patches of habitat (i.e., not manipulated habitats such as rice fields or duck clubs) that are larger than a minimum viable size, connected to migratory corridors or other habitat patches, and that conform to the historical location of that habitat type.

3. Water Quality Index

This indicator will provide an overall measure of water quality. Good water quality is essential for the reproduction, rearing, and growth of aquatic organisms. Eutrophication (excessive nutrients) is not a problem in the system currently. Most water quality problems in the system stem from contaminants. Toxicity scores (e.g., exposure-based metrics) for each of the major contaminant categories (selenium, mercury, PCBs, sediment contaminants, pesticides, metals, and PAHs) will be combined into a single index.

GEOMORPHOLOGY

4. River Health Index

This indicator will provide a measure of how free the system's rivers are to be rivers. River meandering and flooding is essential for sediment supply, creating and maintaining habitat, and sustaining many ecological processes. The indicator will combine measures of channel migration (essential for maintaining habitats and the exchange of nutrients), natural flooding, and sediment supply. It will also measure the total length of naturally migrating sections of rivers by adding up the segments that lack riprap, have early successional stages of forests along river banks, have large logs and branches in the river (essential for creating and maintaining fish habitat), and receive enough water flow to sustain river meandering and flooding. Sediment supply will also be incorporated in this indicator as a percentage of the channel's capacity to transport sediment and the area that is flooded at least every 5 years.

5. Marsh Health Index

This indicator will measure the growth and complexity of marshes and mudflats. It will combine a measure of marsh channel complexity (which appears to be a

PROJECT IN ACTION

Watershed Health Assessments

Local agencies and interest groups have been applying the Bay Area Watershed Science Approach (WSA), developed by the San Francisco Estuary Institute, on creeks in Napa, Sonoma, Marin, Santa Clara, Alameda and Contra Costa counties. Through the WSA, participants develop detailed scientific assessments of past and present conditions for sediment sources, water supplies, wildlife habitat and land use, which in turn provide information on the beneficial uses of Bay Area watersheds.

The WSA combines maps of historical conditions with modern aerial photography in a Geographic Information System (GIS) to develop quantitative analyses of changes in landscape and landscape use. These analyses are combined with intensive field studies of existing conditions of the hill slopes, terraces, and stream banks and beds to help explain any major changes in sediment and water supply, and to what extent people have caused these changes.

The WSA can provide baseline watershed assessments to help design stream restoration projects, prioritize resource protection activities and public land acquisition for conservation and preservation purposes, test Best Management Practices (BMPs) for pollution prevention, validate simulation models of watershed processes, explain watershed form and function to local residents, stratify a watershed for sampling water quality, set science-based goals for watershed health, compare one watershed with another, and design programs for monitoring progress or regress relative to local watershed goals. Applications of the WSA yield important new information about the nature of Bay Area watersheds (Collins et. al, SOE Poster, 1999).

➤ MORE INFO? lester@sfei.org

Essential Ecological Indicators - continued

good proxy for habitat quality) with measures of marsh plain elevation and advancement of marsh edge. As data become available on the bathymetry of the Bay, it will also be incorporated.

HYDROLOGY

6. Pre- and Post-Dam Flows

This indicator will measure proximity to pre-disturbance river conditions. The flow of water created and maintained the aquatic habitats that sustained the abundant fish, water fowl, and riparian communities that once existed in the system. Flow has been dramatically altered by dams in this system. This indicator will describe current flow conditions compared to those of the pre-dam era. Mean annual flow, 2-year and 5- year peak flows, spring flows between April and June, and base flows in August and September will be incorporated into a single index and compared to pre-dam parameters. Variation in flows from year to year is also important for maintaining habitats and ecological processes. Flow variation pre- and post-dam will also be incorporated into this indicator.

Note: Additional indicators are still under consideration in order to reflect the natural pattern of variability — both interannual and intra-annual — well as estuarine circulation and salinity patterns.

ENERGY AND NUTRIENT FLOW

7. Productivity Index

The flow of nutrients and the production of food for wild organisms are critical ecological processes. This indicator will measure water column productivity (as evidenced by the annual spring phytoplankton bloom in South Bay and the amount of chlorophyll a in the North Bay and Delta) as well as the contribution of marsh productivity (as measured by tracers of marsh production within suspension feeders like clams). It will also incorporate the absence of toxic algal blooms. These and other measures will be combined into a single index.

NATIVE BIOTA

Five indices will measure the capacity of the system to support the reproduction, rearing, and growth of native plants and animals. The biota were separated into four functional groups that are essential components of the native system and about which there is some information. Representative species within the four functional groups will be selected according to criteria reflecting the species' ecological characteristics: area-limited, dispersal-limited, resource-limited, process-limited, keystone or ecologically pivotal, and endemic. These five biotic indices may be kept separate or combined into a single index.

8. Fish Index

Native anadromous fishes; native resident pelagic fishes in bay, delta, alluvial rivers and upland rivers; and native resident demersal fishes in bay and delta (e.g., sharks and rays)

9. Bird Index

Neotropical migrant songbirds (riparian and landscape); water birds (shorebirds, wading birds, ducks); and raptors.

10. Vegetation Index

Riparian vegetation (alluvial and upland rivers); and wetland vegetation (bay, delta, alluvial rivers).

11. Habitat Specialists

Fragmentation-sensitive species; clapper rail, red-legged frog, salt marsh harvest mouse etc.

12. Decimated Species

A fifth index will describe presence and abundance trends of native species that might have been decimated or extirpated in the system (and that may rebound in successful restoration), such as the native oyster, blue mussels, and the mud mussel.

13. Disturbance

Percent of abundance or biomass of fish, bird, vegetation, and habitat specialists made up of exotic species. San Francisco Bay appears to be one of the most highly invaded estuaries in the world. This indicator will measure the extent to which non-native (exotic) species have replaced native species.

➤ MORE INFO?
terryyoung@environmentaldefense.org

STATE OF THE ESTUARY CONFERENCE BIBLIOGRAPHY

Key on pg.76

PRESENTATIONS

Armor, C. and Hieb, K., CDFG. Impact of Stressors.

Black, M., California Studies Association. Tragic Remedies: A Century of Failed Hatchery Policies on California's Sacramento River. P. 38

Collins, J., SFEI. Effects of the Goals Project. P. 45

Dubrovsky, N.M., USGS. The Groundwater Resource. P. 39

Dudley, T., U.C. Berkeley. The Status and Impacts of Introduced Species in Riverine Ecosystems. P. 54

Grewell, B.J., U.C. Davis. Rare Plant Restoration Opportunities in the San Francisco Estuary. P. 50

Haltiner, J., Philip Williams & Associates. Engineering vs. Mother Nature. P. 30

Harvey, T.E., USFWS. Delta Restoration: Socio-Political Considerations. P. 33

Hieb, K., CDFG. Recovery of Native Invertebrates and Their Habitats.

Jordan, W.R., Univ. of Wisconsin. Strictly Speaking: The Restoration Concept. P. 18

Kimmerer, W., Romberg Tiburon Center for Environmental Studies, SFSU. Recovery of Species and Their Habitats.

Kolb, L., SFBRWQLB. Porter-Cologneat Age 30. P. 16

Kondolf, G.M., U.C. Berkeley. Historical Changes to the San Francisco Bay-Delta Watershed: Implications for Restoration Priorities. P. 6

Leidy, R., USEPA. Historical Distribution and Current Status of Stream Fishes of the San Francisco Estuary: Opportunities for Protection and Restoration of Native Fish Assemblages. P. 19

Leopold, Luna., UC Berkeley, Fate of the Estuary. P. 60

Luoma, S.N., USGS. Status and Trends of Chemical Contamination in the San Francisco Bay Estuary: Implications for Rehabilitation. P. 56

McBain, S., McBain and Trush. Alluvial River Restoration. P. 26

Monismith, S., Stanford University. Numerical Models Implications of Restoration and Water Project Alternatives. P. 62

Monroe, M., USEPA. San Francisco Baylands Ecosystem Habitat Goals. P. 42

Mount, J.F., U.C. Davis. Floods and Floodplains in the Sacramento/San Joaquin Watershed. P. 28

Moyle, P.B., U.C. Davis. Recovery of Aquatic Species and Their Habitats. P. 34

Mumley, T., SFBRWQCB. The Legacy of Urban Watershed Management.

Page, G., Point Reyes Bird Observatory. Salt Marsh Restoration in the San Francisco Bay Estuary and Implications for Migratory Waterbirds of the Pacific Flyway. P. 52

Schmutte, C., DWR. Restoration of Delta Levees and Habitat. P. 31

Simenstad, C.A., Univ. of Washington. (Re)Turn of the Tide: Promise and Uncertainty in Tidal Marsh Restoration. P. 40

Smith, L., USGS. Can A Large-Scale Science Program Be Sustained?

Stallcup, R., Point Reyes Bird Observatory. Tringa Habitat: Special Needs for Special Birds. P. 52

Trulio, L., SJSU. Terrestrial Species: The Importance of the Wetland-Upland Interface. P. 46

Williams, P.B., Philip Williams & Associates. The Changing Watershed: Dams and Diversions. P. 24

Young, T.F., Environmental Defense. Developing Essential Ecological Indicators for the San Francisco Bay/Delta/River System. P. 70

Zedler, J.B., Univ. of Wisconsin. Improving Strategies for Large-Scale Ecosystem Restoration. P. 66

POSTERS

Abu-Saba, K.E., San Francisco Estuary Project; A.R. Flegal, U.C. Santa Cruz. Coupled Fluvial and Benthic Inputs Lead to Contrasting Distributions of Copper and Lead in San Francisco Bay.

Anderson, B., J. Hunt, B. Phillips, R. Tjeerdema, U.C. Santa Cruz; R. Fairey, SJSU; M. Martin, DFG. Ecotoxicological Monitoring at a Remediated Superfund Site - Lauritzen Channel. P. 58

Ayres, Debra, Dino Garcia-Rossi, Heather Davis and Don Strong, U.C. Davis. Smooth and California Cordgrass and Their Hybrids in San Francisco Bay. P. 54

Bach, Carol, Port of San Francisco; Roger Leventhal, Levine-Fricke-Recon. Creating a Public Urban Wilderness on San Francisco Bay - The Pier 98 Wetlands Restoration and Public Access Project. P. 44

Bennett, William, U.C. Davis; Elizabeth Howard, USBR. Behavioral Response to Climate Change and the Decline of Striped Bass in the San Francisco Estuary. P. 34

Bergamaschi, B.A., USGS; R.G. Keil, Univ. of Washington; and D.S. Baston, U.S.G.S. The Relationship Between Organic Carbon Loadings and Pesticide Content in Field-Flow Fractionated Sediments from the San Francisco Bay Estuary, California, USA.

Bleifuss, Alistair, Council of Bay Area Resource Conservation Districts. Equine Facilities Assistance Program.

Bouse, R., S. Luoma, M. Hornberger, B. Jaffe and R. Smith, USGS. Remobilization of Historical Metal Contamination in San Francisco Bay Sediments. P. 57

Breaux, Andree, SFBRWQCB. Preserving Habitat for Native Mammals, Amphibians, Reptiles, and Terrestrial Invertebrates in the San Francisco Bay Region.

Breaux, Andree, SFBRWQCB. The Use of Unstable Performance Criteria to Implement a Stable No-Net-Loss Policy. P. 66

Brorby, G., Brad Job, Amanda Spencer and Dawn Zemo, Geomatrix Consultants, Inc. An Argument Against Developing TPH-Based Tier 1 Ecological Screening Values to Evaluate Petroleum Hydrocarbon Releases to Soil and Groundwater.

Brown, C.L., F. Parchaso, J.K. Thompson, and S.N. Luoma, USGS. The Effects of Cd and Ag on Condition and Reproduction in Potamocorbula amurensis in Northern San Francisco Bay.

Buisson, E., L. Castellini, J. Harwayne, J. Miller, S. Pauquet, J. Pearson, A. Swinehart, P. Zimmerman, M. Josselyn, Romberg Tiburon Center for Environmental Studies, SFSU. Comparison of Wetland Functions in Restored Tidal Marshes of Varying Ages. P. 40

Cappiella, K., C. Malzone, R. Smith and B. Jaffe, USGS. Sedimentation and Bathymetric Changes in Suisun Bay: 1867-1990.

Clark, S.L., U.C. Davis; C.L. Brown, USGS; and D.E. Hinton, U.C. Davis. Linkage of Tissue Alterations to Body Burden and Condition Index in the Asian Clam (Potamocorbula amurensis) from San Francisco Bay.

Cochrane, Steve, Friends of the Estuary. Creek Keepers

Collins, Joshua, Robin Grossinger and Zoltan Der, SFEI. The Bay Area EcoAtlas.

Collins, Laurel, Joshua Collins, Rainer Hoenicke, Robin Grossinger, SFEI. A Bay Area Watersheds Science Approach. P. 72

Creager, Clayton, Gary Wortham, Tom Grieb, and Jon Butcher, Tetra Tech, Inc. South San Francisco Bay Beneficial Use Impairment Assessment for the Copper and Nickel Total Maximum Daily Loads.

Daum, Ted and Bruce Thompson, SFEI; Gregory Bartow, SFBRWQCB; Rob Toia, U.C.S.F. Sediment Contamination in San Leandro Bay, CA - A Watershed Based Investigation.

Davis, J.A., M. May and S.E. Wainwright; R. Fairey, C. Roberts, and G. Ichikawa, Moss Landing Marine Lab; R. Tjeerdema, M. Stoelting, and J. Becker, U.C. Santa Cruz; M. Petreas, CalEPA; and K. Taberski, SFBRWQCB. Persistent Toxic Chemicals of Human Health Concern in Fish from San Francisco Bay and Sacramento River, CA. P. 14 & P. 56

DeLeon, S., K. Hieb, and Tom Greiner, DFG. Quantitative Sampling of Fishes in Several San Francisco Bay Tidal Marsh Habitats.

Der, Zoltan, Robin Grossinger, Christina Wong and Joshua Collins, SFEI. Choosing the Best Map: Availability, Accuracy and Accountability. P. 64

Dinehart, Randal, and David Schoellhamer, USGS. Sedimentation in the Delta of the Sacramento and San Joaquin Rivers.

Disney, Michele and A. Keith Miles, USGS. Effects of Soil Organic Content and Surface Litter (Mulch) on Pickleweed *(Salicornia virginica)* Establishment along Suisin Bay. P. 50

Edmonds, Jody, Kathy Kuivila, Brian Cole and James Cloern, USGS. Do Herbicides Impair Phytoplankton Primary Production in the Sacramento-San Joaquin River Delta?

Edwards, George, Doug Killam, Bob Fujimura, Leslie Milett and Ted Frink, DWR. Evaluation of Modifications to the Suisun Marsh Salinity Control Gates on Adult, Fall-Run Chinook Salmon Passage.

Enright, Chris, Kate Le, Kamyar Guivetchi, DWR. Progress in Modeling Salinity Impacts of Suisun Levee Breaches. P. 63

Ganguli, Priya, U.S. Santa Cruz; R.P Mason, Chesapeake Biological Laboratory; R.S. Anderson and A.R. Flegal, U.C. Santa Cruz. Transport of Mercury from the New Idria Quicksilver Mine to the San Joaquin Valley Drainage Basin.

Garcia, M.H., U.C. Berkeley. *Potamocorbula Amurensis*, From Oocyte to Metamorphosis.

Goldbeck, Steven, SFBCDC. Hamilton Army Airfield Wetland Restoration Project, P. 49

Grimaldo, Lenny, Zachary Hymanson, Robert Miller and Chris Peregrin, DWR. Restoration of Tidal Perennial Wetlands in the Sacramento-San Joaquin Delta: Will it Provide the Expected Ecosystem Benefits to Native Fish? P. 31

Grossinger, R., J. Collins, E. Brewster, Z. Der, SFEI. Historical Ecology Research in the San Francisco Bay Area, California.

Grossinger, R., J. Collins, Z. Der, E. Brewster, SFEI. Landscape Change in the Baylands Ecosystem of the San Francisco Estuary, California.

Hitchcock, Nadine, California Coastal Conservancy. San Francisco Bay Area Conservancy Program.

Hoenicke, Rainer, Ted Daum, Jay Davis, and Lauren Gravitz, SFEI. Contributions of Chlorinated Hydrocarbons to the Estuary from Two South Bay Watersheds.

Holmgren, Sarah, Montgomery Watson; Jim McKevitt and Larry Puckett, USFWS. An Inventory of Restoration Activities for Anadromous Fish Throughout California's Central Valley.

Hornberger, M.I., S.N. Luoma, D.J. Cain, F. Parchaso, C.L. Brown, R.M. Bouse, C. Wellise, J. Thompson, U.S.G.S. Bioaccumulation of Metals by the Bivalve *Macoma balthica* at a Site in South San Francisco Bay Between 1977 and 1997: Long-term Trends and Associated Biological Effects with Changing Pollutant Loadings. P. 15 & P. 59

Huang, Charlie, and Don Guy, CDFG. Environmental Monitoring for Chemical Control of Egeria densa in the Sacramento/San Joaquin Delta, 1998.

Hui, Clifford, USGS Elemental Contaminants in the Livers and Ingesta of Four Subpopulations of the American Coot (Fulica Americana): An Herbivorous Winter Migrant in San Francisco Bay. P. 15

Hunt, J.W., B.S. Anderson, B.M. Phillips, R.S. Tjeerdema, U.C. Santa Cruz; R. Fairey, Moss Landing Marine Lab; H.M. Puckett, M. Stephenson, CDFG; K.M. Taberski, SFBRWQCB. Sediment Toxicity in San Francisco Bay: Screening for Hot Spots, Investigating Sources and Causes. P. 14

Jaffe, Cores B., R. Smith, K. Cappiella, R. Bouse, S. Luoma, M. Hornberger, USGS. Modeling the Distribution of Mercury-Contaminated Hydraulic Gold Mining Debris in San Francisco Bay using Historical Hydrographic Surveys and Sediment. P. 57

Job, Brad, and Gregory Brorby, Geomatrix Consultants, Inc. Feasible Alternatives to TPH-Based Tier 1 Ecological Screening Levels to Evaluate Petroleum Hydrocarbon Releases to Soil and Groundwater.

Kilgour, Laura, Alameda County Flood Control and Water Conservation District. Tule Ponds Stormwater Treatment System.

Knowles, N., D. Cayan, M. Dettinger, D. Peterson and R. Smith, USGS. How and on What Time Scales Does Climate Influence San Francisco Bay/Delta Water Management?

Kopec, D. and C. Spencer, Earth Island Institute. Ground and Aerial Census of Harbor Seals in San Francisco Bay: 1995-1997.

Kramer, Kathy, Aquatic Outreach Institute. Involving the Public in Habitat Restoration and Watershed Management.

Kuivila, Kathryn, Holly Barnett, and Jody Edmunds, USGS. Herbicide Concentrations in the Sacramento-San Joaquin Delta, California. P. 58

Kuwabara, James, Frederic Nichols, Kathryn Kuivila and Jeanne Dileo, USGS. Understanding the Human Influence on the San Francisco Bay-Delta Estuary Ecosystem - The Toxic Substances Hydrology Program and USGS Place-based Studies Program Provide Complimentary Approaches and Results.

Kuwabara, James, USGS.; Brent Topping, USGS.; Kenneth Coale, Moss Landing Marine Laboratory; and William Berelson, USC. Fate and Effects of Metal Contaminants: Solute Remobilization into the Water Column of San Francisco Bay.

Langis, Rene, CH2M Hill; Linda Ngim, U.S. Army Corps of Engineers; Earl Byron, CH2M Hill; Kyle Winslow, CH2M Hill; Peter LaCivita, U.S. Army Corps of Engineers. *In-situ* Use of Irradiance and Turbidity to Monitor Potential Impacts to Eelgrass *(Zostera marina)* Beds During Dredging Episodes in San Francisco Bay. P. 69

Lehman, P.W., DWR. The Influence of Climate on Environmental and Biological Trends in the San Francisco Bay-Delta Estuary.

Leventhal, R., Levine-Fricke; J. Zaitlin, Port of Oakland; K. Lenington, SFSU; A. Breaux, SFBRWQCB; S. Granholm, LSA Associates; A. Feinstein, Golden Gate Audubon Society. Restoring the Tides. The First Nine Months of the Martin Luther King, Jr. Wetlands Restoration Project, Oakland, California.

Lincoff, A., USEPA; N. Kohn, Battelle Marine Sciences Laboratory; and R. Vesperman, USEPA. The United Heckathorn Superfund Site: NPL Listing to Sediment Remediation. P. 58

Lingl, Herb, Aerial Archives and Herb Lingl Aerial Photography. Using Aerial Photography to Document the Evolving State of the Estuary.

Lowe, Sarah, and Bruce Thompson, SFEI. An Approach to Identifying Benthic Community Responses to Contamination in the San Francisco Bay.

Matern, Scott, and Peter Moyle, U.C. Davis. The Recent Invasion of the Shimofuri goby (Tridentiger bifasciatus) into California: establishment, potential for spread, and likely effects. P. 11

McGann, Mary, USGS Vertical Distribution of Foraminifers, Including the Non-Indigenous Species Trochammina Hadai, in South San Francisco Bay.

McGowan, Michael, Robert Abbott, Barry Hecht and Bruce Lord, Romberg Tiburon Center for Environmental Studies, SFSU. Guidelines for Evaluating Dam Removal or Modification to Improve Fish Habitat. P. 25

McKnight, Oona, Mitchell Katzel, Sonoma Valley Watershed Station/Sonoma Ecology Center. Assessment of Potential Limiting Factors for Steelhead Trout in the Sonoma Valley Watershed. P. 19

Michaud, J., Sonoma State University; D. Kopec, Earth Island Institute; D. Girman, Sonoma State University. Conservation Genetics of San Francisco Bay Harbor Seals (Phoca vitulina).

Mills, W., and T. Grieb, Tetra Tech, Inc. Conceptual Model of Copper and Nickel Cycling in Lower South San Francisco Bay.

Moran, Kelly, Palo Alto Regional Water Quality Control Plant; William Johnson, EIP Associates. Sources of Mercury Discharges to the Palo Alto Regional Water Quality Control Plant.

Morrison, D., USFWS. Proposed Indicators of Ecological Integrity for the CALFED Bay-Delta Ecosystem Restoration Program. P. 70

Nur, N., T. Gardali, Y. Chan, G. Geupel and S. Zack, Point Reyes Bird Observatory. Population Ecology and Habitat Needs of Four Potentially Threatened Tidal Marsh Subspecies: Song Sparrows and Yellowthroats of San Francisco Estuary.

Nute, W. Edward, Nute Engineering. Las Gallinas Valley Sanitary District Wastewater Reclamation Project.

Olson, Brad, East Bay Regional Park District. East Bay Regional Park District Environmental Partnerships: Acquisition, Enhancement and Restoration Projects along the East Bay Shoreline. P. 64

Oltmann, Richard, and Michael Simpson, USGS. Measurement of Tidal Flows in the Sacramento-San Joaquin Delta, California.

Orr, Michelle, Philip Williams, Philip Williams and Associates; Denise Reed, University of New Orleans. Sacramento-San Joaquin Delta Breached-Levee Wetland Study: A Conceptual Model of the Geomorphic Evolution of Freshwater Tidal Wetlands.

Pawley, Anitra, and Brian Largay, The Bay Institute. Coupling Hydrologic and Ecological Models for Application in River Management and Restoration. P. 62

Peabody, Carey, and Karen Gruebel, Erler and Kalinowski, Inc. Restoration of Groundwater in Distributory Channel Sediments at San Francisco Bay Margin.

Peterson, D., R. Smith, D. Cayan, M. Dettinger and N. Knowles, USGS. Forecasting Spring Discharge.

Phillips, Bryn, Brian Anderson and John Hunt, U.C. Santa Cruz. Investigating Causes of Sediment Toxicity in the San Francisco Bay/Delta.

Phipps, Jeff, Consultant to CALFED. Category III Project Objectives and Monitoring Approaches.

Redpath, George, Tetra Tech, Inc. Common Reed *(Phragmites australis)* Control. P. 55

Reed, Denise, and Wendy Morrison, University of New Orleans. Contemporary Rate of Sedimentation and Elevation Change in Tidal Wetlands of the Sacramento-San Joaquin Delta: Preliminary Results.

Roberts, Thomas, and Leslie Moulton, ESA for the Bay Area Recycling Program Master Plan. Environmental Reuse of Water for Estuary Rehabilitation: Stream Augmentation and Marshland Restoration Using Recycled Water.

Ruhl, C., D. Schoellhamer, R. Stumpf, and C. Lindsay, USGS. Remote Sensing: Visual Cues to Suspended-Solids Transport in San Francisco Bay, California.

Schemel, L.E., S.W. Hager and D.H. Peterson, USGS Reduced Phosphate Loading to South San Francisco Bay: Detection of Effects in the Water Column.

Schmidt, D., USEPA. San Francisco Bay Area Environmental History Atlas.

Siegel, Stuart, U.C. Berkeley. Geomorphic Processes in the Evolution of a Restored Estuarine Tidal Marsh. P. 41

Simenstad, Charles, Jeffery Cordell, Jason Toft, University of Washington; Denise Reed, University of New Orleans; Philip Williams and Michelle Orr, Philip Williams and Associates; Zachary Hymanson and Lenny Grimaldo, DWR. Predicting the Outcome and Timeframe for Restoration of Reflooded Wetlands in the Sacramento-San Joaquin Delta: The CALFED Category III "Breach" Project. P. 53

Slotton, Darell G., Thomas H.Suchanek, Shaun M. Ayers, Brenda Johnson, Chance MacDonald, and Douglas C. Nelson, University of California, Davis. Potential Methyl Mercury Consequences of Bay-Delta Wetlands Restoration Projects. P. 57

Sommer, Ted, Bill Harrell and Matt Nobriga, DWR; Larry Schemel, USGS The Yolo Bypass Floodplain: Chicken Soup for the Estuary. P. 29

Starner, Keith, Kathryn Kuivila, Bryan Jennings and G. Edward Moon, USGS. Laboratory Experiments Estimating Total Degradation Rates of Select Pesticides in the Sacramento River, California.

Starratt, S.W., USGS Diatom Evidence for Fluctuations in the Freshwater Budget of Northern San Francisco Bay: A 3,000 Year Record.

Steding, Douglas, and A.R. Flegal, U.C. Santa Cruz. Recent Variations in Lead Isotopic Ratios in San Francisco Bay Reflect a Change in Source(s) Associated with the Elimination of Leaded Gasoline in California.

Teh, Swee, Inge Werner, and David Hinton, U.C. Davis. Chronic Toxicity of Chromium VI in Asian Clam (Potamocorbula amurensis): A Biochemical, Immunohistochemical and Histopathological Approach.

Toft, Jason, Charles Simenstad, Jeffery Cordell, University of Washington. The Effect of the Exotic Aquatic Plant *Eichhornia Crassipes* (Water Hyacinth) on the Fish/Invertebrate Food Web in the Sacramento/San Joaquin Delta, California.

Topping, Brent, and James Kuwabara, U.S.G.S. Low-Volume, Multi-Trace-Element Determinations for San Francisco Bay by Flow-Injection-ICP-MS.

Torresan, L., R. Lugo, R. Smith, L. Gaydos, and R. Sanders, U.S.G.S. Acquiring Data from and Information on the Latest USGS Research in San Francisco Bay and Delta: The "Access USGS - San Francisco Bay and Delta" WWW Server.

Vorster, Peter, The Bay Institute; Brian Cohen, GreenInfo Network. Geographical Information System (GIS) Maps Comparing Historical and Current Aquatic Habitats of the San Francisco Bay-Delta Watershed.

Warner, John, U.C. Davis; David Schoellhamer, U.S.G.S.; S.G. Schladow, U.C. Davis; Jon Burau, USGS. Napa/Sonoma Marsh Hydrodynamic and Water-Quality Study.

Werner, Inge, and D.E. Hinton, U.C. Davis. Spatial and Temporal Profiles of Stress Protein (HSP70) and Metallothionein in Asian Clam (Potamocorbula amurensis) in Northern San Francisco Bay.

West, J., Madrina Group. Mission Creek Bikeway and Greenbelt, San Francisco.

Winternitz, Leo, DWR; Tom Harvey, USFWS; Walt Hoye, MWD; Will Keck, USBR. Prospect Island Restoration Project and Monitoring Plan. P. 32

Wright, Scott, and Philip Williams, Philip Williams and Associates. Napa River Restoration and Floodplain Management. P. 28

Zawislanski, P.T., H.S. Mountford, A.E. McGrath, E. Gabet, H.-W.C. Wong, S. Chau, Lawrence Berkeley National Laboratory. Selenium and Heavy Metal Dynamics in Intertidal Wetlands in the Carquinez Strait. P. 56

SUPPORTING BIBLIOGRAPHY

Albertson, J. and J. Evens. 1998. Species Account for the San Francisco Bay Goals Project Report: California Clapper Rail. P. 12

Bay Institute. 1998. *From the Sierra to the sea: the ecological history of the San Francisco Bay-Delta Watershed*. The Bay Institute, San Rafael, California.

Belitz, Kenneth and F.J. Heimes. 1990. Character and evolution of the groundwater flow system in the central part of the western San Joaquin Valley, California. USGS Water Supply Paper 2348, 28 pp.

CALFED Bay-Delta Program. 1999. *Ecosystem Restoration Program Plan Volume I. Ecological Attributes of the San Francisco Bay-Delta Watershed*. Draft programmatic EIS/EIR Technical Appendix. CALFED, Sacramento, California.

Caywood, M.L. 1974. Contributions to the Life History of the Splittail *Pogonichthys macrolepidotus* (Ayres). M.S. Thesis, California State University, Sacramento. 77pp.

Dudley, T. 1998. Exotic plant invasions in California riparian areas and wetlands. *Fremontia* 26:24-29.

Dudley, T. and B. Collins. 1995. Biological invasions in California wetlands: the impacts and control of non-indigenous species in natural areas. Pacific Institute for SIDES, Oakland.

Evens, J. Page, Gary, Laymon, Stephen, and Stallcup, R. *The Condor* 93:952-966. 1991. 952-966.

Frahm, Annette, et al. 1996. Changing Behavior: Insights and Applications. Local Hazardous Waste Management Program in King County, Seattle.

Goals Project. 1999. *Baylands Ecosystem Habitat Goals. A report of habitat recommendations prepared by the San Francisco Bay Area Wetlands Ecosystem Goals Project.* USEPA, San Francisco, Calif. SFBR-WQCB, Oakland, Calif.

Healey, M., W. Kimmerer, G.M. Kondolf, R. Meade, P.B. Moyle, and R. Twiss.1998. *Strategic Plan for the Ecosystem Restoration Program*. CALFED, Sacramento, California..

Holling, C.S. 1978. Adaptive Environmental Assessment and Management. Edited by John Wiley & Sons.

Hornberger, M.I., S.N. Luoma, A. Van Gee., C. Fuller & R. Anima. 1999a. Historical trends in metals in the sediments of South San Francisco Bay, California. *Mar. Chemistry* 64:39-56

Hornberger, M.I., S.N. Luoma, D.Cain, F. Parchaso, C. Brown, R. Bouse, C. Wellise & J. Thompson. 1999b. Bioaccumulation of metals by the bivalve Macoma balthica at a site in South San Francisco Bay between 1977 and 1997: Long-term trends and associated biological effects with changing pollutant loadings. USGS Open File Report 99-55.

Hui, C. A. 1998. Elemental contaminants in the livers and ingesta of four subpopulations of the American coot (Fulica americana): an herbivorous winter migrant in San Francisco Bay. *Environmental Pollution* 101:321-329.

Hunt, J.W., Anderson, B.S., Phillips, B.M., Newman, J., Tjeerdema, R.S., Stephenson, M., Puckett, H.M., Fairey, R., Smith, RW, and Taberski, K. 1998b. Evaluation and use of sediment reference sites and toxicity tests in San Francisco Bay. Bay Protection and Toxic Cleanup Program Final Technical Report. SWRCB, Sacramento, CA. pp 132.

Hunt, J.W., Anderson, B.S., Phillips, B.M., Newman, J., Tjeerdema, R.S., Taberski, K, Wilson, C.J., Stephenson, M., Puckett, H.M., Fairey, R., and Oakden, J. 1998a. Sediment Quality and Biological Effects in San Francisco Bay. Bay Protection and Toxic Cleanup Program Final Technical Report. SWRCB, Sacramento, CA. pp 188.

Kondolf, G.M., and M. Larson. 1995. Historical channel analysis and its application to riparian and aquatic habitat restoration. *Aquatic Conservation* 5:109-126.

McBain & Trush. 1999. *Habitat Restoration Plan for the Lower Tuolumne River Corridor*.

Meng, L., and P.B. Moyle. 1995. Status of Splittail in the Sacramento-San Joaquin Estuary. Transactions of the American Fisheries Society 124: 538-49.

Nur, Nadav, Steve Zack, Jules Evens, and Thomas Gardal. 1997. Tidal Marsh Birds of the SF Bay Region: Status, Distribution, and Conservation of Five Category 2 Taxa, Draft Final Report.

Regional Monitoring Program. 2000. *The Pulse of the Estuary: Tracking Contamination with the Regional Monitoring Program* 1993-1998. SFEI, Richmond, California

Ritson, P.I., R.M. Bouse, A.R. Flegal & S.N. Luoma. 1999. Stable lead isotopic analysis of hisotric and contemporary lead contamination in the San Francisco Bay estuary. Mar. Chemistry 64: 71-84

SFBRWCB. 1995. Contaminant Levels in Fish Tissue from San Francisco Bay: Final Report. Oakland, CA.

San Francisco Estuary Project. 1999. *Bay-Delta Environmental Report Card*

San Francisco Estuary Project. 1997. *State of the Estuary Report*

San Francisco Estuary Project. 1992. *Status and Trends Report on Wildlife of the San Francisco Estuary.* USFWS, Sacramento, CA.

Simenstad, C., J. Toft, H. Higgins, J. Cordell, M. Orr, P. Williams, L. Grimaldo, Z. Hymanson and D. Reed. 1999. Preliminary results from the Sacramento-San Joaquin Delta Breached Levee Wetland Study (BREACH). IEP Newsletter 4: 15-21.

Spies, R.B., D.W. Rice & J. Felton. 1988. Effects of organic contaminants on reproduction of starry flounder platichthys stellas in San Francisco Bay. Mar. Biol. 98: 181-189.

Urquhart, K. & Regaldo, K. 1991. Selenium Verification Study, 1988-1990. Water Resources Control Board Publ. 91-2-WQ.

Zedler, J.B. and J.C. Calloway. 1999. Tracking wetland restoration: Do mitigation sites follow desired trajectories? *Restoration Ecology* 7:69-73

ACRONYMS KEY

DWR-Department of Water Resources

CALFED-CALFED Bay-Delta Program

CDFG-California Department of Fish and Game

MWD-Metropolitan Water District

SFBCDC-San Francisco Bay Conservation and Development Commission

SFBRWQCB-San Francisco Bay Regional Water Quality Control Board

SFEI-San Francisco Estuary Insitute

SFEP-San Francisco Estuary Project

SJSU-San Jose State University

SWRCB-State Water Resources Control Board

USBR-United States Bureau of Reclamation

USEPA-United States Environmental Protection Agency

USFWS-United States Fish and Wildlife Service

USGS-United States Geological Survey

Page numbers appearing in bold refer to the page number in this report.